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SCIENCE, ENVIRONMENT, AND TECHNOLOGY SUMMIT: A LONG TERM NATIONAL SCIENCE STRATEGY

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Science, Environment, and Technolog...

HEARING

BEFORE THE

SUBCOMMITTEE ON BASIC RESEARCH

OF THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

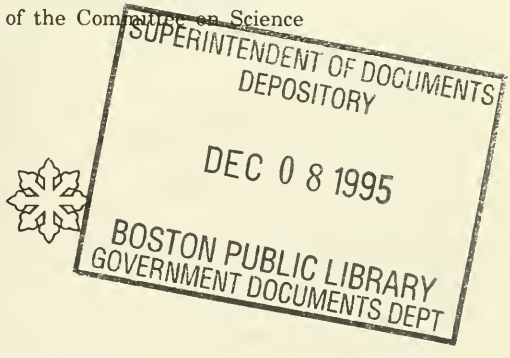
ONE HUNDRED FOURTH CONGRESS

FIRST SESSION

JUNE 1, 1995

[No. 17]

Printed for the use of the Committee on Science



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SCIENCE, ENVIRONMENT, AND TECHNOLOGY SUMMIT: A LONG TERM NATIONAL SCIENCE STRATEGY

THURSDAY, JUNE 1, 1995

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
SUBCOMMITTEE ON BASIC RESEARCH,
Washington, DC.

Chairman STEVEN SCHIFF. I'd like to open the hearing of the Subcommittee on Basic Research of the Science Committee of the U.S. House of Representatives. I'd like to welcome everybody here.

I would like to begin by introducing myself: My name is Steven Schiff, I'm the Chairman of the Subcommittee and I'm representing the First District of New Mexico. And I'm very happy to be back in Tennessee once again, very proud to be back in Tennessee to be able to share this hearing here.

I have a brief prepared written statement that I'd ask unanimous consent to enter into the record. Without objection, entered. And I have a couple of very brief personal remarks: The first is, before I introduce our panel to begin their testimony, the first is, I just want to talk for a moment about the three individuals seated to my right.

I was elected to Congress in 1988, and although every freshman member of Congress intends on changing the world, when you get there, first you have to learn where your committee rooms are, you know, a few basic things like that. And a person who helped me find out where everything was and how it operated was the chairman of the first subcommittee I was assigned to, which was the Energy Research Subcommittee of the House Science Committee. And that is former Congresswoman Marilyn Lloyd.

And I've learned a great deal from Congresswoman Lloyd. I would say the most important lesson of which was, there will be no partisanship in the science view. We may have different views as individuals, but we're not going to bring floor fights into the dealings on U.S. Science—we're all going to be on the same team there. And now that I have a chair, I try to emulate your record, Congresswoman Lloyd. We welcome you and thank you for being here today.

Well, I said that every freshman member of Congress believes they're going to change the world. One who's well on his way to doing so is your present Congressman, Zach Wamp. [Audience applauds.]

Now I want to tell you, this is the first field hearing meeting outside of Washington that I've conducted. For obvious cost reasons, we don't do them very often. But Zach has been so interested and so innovative and so energetic in working on science issues, made obvious by putting together this entire Summit here at Oak Ridge National Laboratory, that I felt he had earned the first right to have a Subcommittee hearing in his district. And, in fact, before this, I appointed him Vice Chairman of the Basic Research Subcommittee, and am very happy with that choice.

And last—but as they say, not least—another new member of Congress who is very active in science issues, particularly dealing with aeronautic issues, is Congressman Van Hilleary who's here with us also. Also, as you know, from Tennessee.

Now, before I let each of my three colleagues make whatever remarks they'd like to make, I'd like to say just one more thing: And that is, as you well know, Congress has begun the budget struggles to try to reach a balanced budget in the next seven years. In my view—speaking personally, not necessarily for any other member, Democrat or Republican—to me, that is a non-negotiable goal. That is, balancing the budget. It's something that's long overdue—it is something that should have been addressed many years ago—it was not. No sense going back and assessing blame for that, it's going to be done now.

However, I do believe that how we are to get a balanced budget is negotiable; how we put together the figures, you can have legitimate debate about. And I think that in the House Budget Committee Resolution which passed the House of Representatives, I think the most serious disagreement I have with that resolution and the priorities it set is specifically with respect to the Department of Energy and with scientific research.

As you know, it proposes the dissolution of the Department of Energy. I think that's a serious mistake; if for no other reason, no one else has the expertise to safely manage the nuclear weapons program.

Second of all, there are various scientific programs which one could argue perhaps should be elsewhere in the Administration, but in my view, a strong commitment to science is not only important for the sake of human understanding, but I think it's an absolute necessity in an increasingly inter-competitive world. It's my understanding that in other industrialized countries they use all of their assets together: government, their national laboratories, their universities, their private enterprise. They collaborate.

It seems to me that we in this country should use all of our intellectual assets to work for a stronger U.S. economy the same way other countries are working for their economies. And I think it's another mistake to believe that you can take the strong intellectual assets that we have in our laboratories—whether it's Oak Ridge National Laboratory here or Sandia National Laboratory back in my district—and believe that they should be kept totally apart from other developments in your economy, in your society. So those are issues that will continue to be addressed as we continue on the budget process.

With that, I would like to yield to my former Chair, Marilyn Lloyd.

[The prepared opening statement of Mr. Schiff follows:]

OPENING STATEMENT

CHAIRMAN STEVEN SCHIFF
SUBCOMMITTEE ON BASIC RESEARCH
COMMITTEE ON SCIENCE
U. S. HOUSE OF REPRESENTATIVES

OAK RIDGE FIELD HEARING

JUNE 1, 1995

The Subcommittee on Basic Research is convening this afternoon in Oak Ridge for the purpose of receiving testimony on the long-term future of Federally-supported science and technology. This hearing is being conducted as part of the Oak Ridge Summit on Science, Environment and Technology, a precedent-setting regional colloquium hosted by the Vice-Chairman of my Subcommittee, Congressman Zach Wamp. I first want to acknowledge Congressman Wamp's efforts in assembling this two-day summit and commend him for his foresight and energy in pulling together government, academic, and industrial leaders in discussions of their future relationships in charting Tennessee's and America's future.

I should state up front that I have my own parochial reasons for chairing this hearing in that I find my home town of Albuquerque in a very similar situation to that here in Oak Ridge. I, too, have a national laboratory -- Sandia -- in my district and another just up the road in Los Alamos. I, too, have a major research university and a growing interest on the part of my state and local governments, and our industry, in advancing our state's and America's competitive future.

Our subject this afternoon of a long-term science strategy is particularly timely, for America's science and technology enterprise has entered a new era for at least three reasons:

First, the Cold War has ended, and while the world is still a very dangerous and unpredictable place, the national security mission which has driven our science and technology base since World War II has fundamentally changed.

Second, the clarion call to our Federal government to begin reducing its annual deficit and balance the budget will have profound implications on all spending programs, including Federal support for science and technology. I note that the current Administration's projections for future spending, as well as the Budget Resolutions recently passed by the U. S. House and Senate, show trends of reduced Federal support for research and development. The direction we are proposing is the same -- only the pace is still open for discussion.

Third, the role of the Federal government -- and other levels of government -- in assisting American industry in job creation, and in the increasingly competitive world markets, is one of continuing discussion.

Our discussions today fit neatly into other ongoing national discussions on how the relationships between our research universities, our industries (large and small) and our governments (Federal, state, and local)

must now evolve to assure a healthy science and technology base for our nation. In addition, there are ongoing discussions about how the organization of our Federal science agencies might evolve to improve the efficiency of delivering dollars to researchers. In particular, creation of a Federal Department of Science to organize the orphaned science sub-Cabinet agencies created by the proposed dissolution of Federal departments, like Energy and Commerce, is being proposed again by my full Committee Chairman.

But, I am not here today to propose solutions, but rather to engage in a continuing dialogue which will hopefully help define a new paradigm for American science and technology.

Before closing, I would like to recognize the presence of Marilyn Lloyd, a former colleague and longtime subcommittee Chairman of the Science Committee. She has joined us today at my -- and Zach Wamp's -- invitation to participate in this dialogue.

Former Congresswoman MARILYN LLOYD. Thank you very much, Mr. Chairman. I want you to know how much I appreciate the opportunity to be a part of this panel today. I have never, in my twenty years of Congress, known of a former member invite anybody to sit in on a panel of a Congressional Committee, and I want to tell you how much I appreciate it. Thank you, Zach, thank you, Van. And congratulations, you're doing a great job.

[Whereupon, Ms. Lloyd and Mr. Wamp shake hands and audience applauds.]

Former Congresswoman MARILYN LLOYD. It's really a real delight to find out that I could participate in this hearing on long-term science strategy. We pretty well know our budget numbers, we know the financial constraints that are ahead. We have the Secretary's alignment in downsize initiative as well as the Galvin recommendations. And in many instances, they will serve as roadmaps.

So, right now, congratulations, Zach, because this is the perfect time for this hearing, to consider ways that our nation can best prioritize and support our worthy and our promising science and technology programs that are so critical to our nation's future well being.

As a member of this Committee for twenty years, I believe that I can make the following observation: I know full well that long-term planning is essential to success. In fact, our starts and our stops have resulted in wasted tax dollars and lack of scientific progress. And all too often, the lack of continuity or lack of anticipated progress and long lead time in research and development, ladies and gentlemen, has been political and not scientific.

Unfortunately, all too often, there has been ambivalence and a lack of commitment by the Congress and Executive Branch to fund the worthy programs at a level that projected the necessary progress or anticipated performance. The list of these cutbacks and cancellations are lengthy, but I'm sure that most people in this room know them by heart. But even with the cutbacks, we can lead and we will succeed.

I believe that research and development funding for joint ventures has proven successful and certainly should be continued. Mr. Chairman, I urge you and my colleagues to continue their support for the Department of Energy. Because of the nature of research, there will be, and continue to be, a need for a Federal role in energy research and development. This is investing wisely—to enhance the security, the opportunities, and the prosperity for our nation. Thank you, Mr. Chairman. [Audience applauds.]

Chairman STEVEN SCHIFF. Obviously, Marilyn, they still remember you. Well, Zach, it appears you don't need an introduction, they know you, too. I now recognize Congressman Zach Wamp.

Congressman ZACH WAMP. Thank you, Mr. Chairman. He used the term, a minute ago, intellectual asset, and I think that Steve Schiff is one of the intellectual assets of the United States House of Representatives. And he's taken me under his wing as Congresswoman Lloyd obviously took him under her wing. And I'm very grateful that he would travel from New Mexico to be in Oak Ridge with us today.

I think that says a lot about this day, the cooperation that we have now developed, why today even New Mexico and Tennessee are working together with regards to science and energy. And that, in and of itself, is probably a historic moment. Thank you, Mr. Chairman, for coming from New Mexico and allowing this hearing to be held.

Congresswoman Lloyd served with distinction. I'm very grateful for her cooperation, not only with the Summit and participating today and tomorrow, but since November the 8th she has proven to us all that she is truly a class act. And she's served with distinction for twenty years; we owe her a great debt of gratitude.

Van Hilleary and I are young and quick studies; he on the wind tunnel projects and me on science and energy, and I'm grateful that he came as well to participate in the Summit, both this afternoon and this evening.

Our distinguished witnesses have come from all across the country. We're very grateful that they took the time and submitted lengthy testimony which you will hear today for our review and anticipation of this hearing as well today.

You know, I think it is good for our nation to discuss and reprioritize the difference between basic and applied research. That is a healthy discussion. But it is bad to treat our National Laboratories as anything less than national jewels. We must stand behind what we have built, developed, and invested in as a Nation. That is what today is about, that's what this Summit is about, that's what this hearing is about.

I agree with our Chairman that the Department of Energy needs to improve, but we need to continue. We need to roll back some regulations and some nonsensical practices in the Department of Energy to make it easier for the people who work there to do the job that we hired them to do. But we do not need to reorganize for the sake of reorganization. And I am here today to make that statement loud and clear.

I thank everyone for their participation. I yield back the balance of my time. [Audience applauds.]

Chairman STEVEN SCHIFF. We're glad now to welcome another member of the Science Committee from Tennessee, Congressman Hilleary.

Congressman VAN HILLEARY. Thank you, Mr. Chairman. I will make my remarks very brief. And sometimes when you're in Washington and you hear a Congressman start out saying my remarks will be very brief, that's the kiss of death, I assure you. You get ready for the long haul, hunker down. But this will be brief.

Thank you, Mr. Chairman, once again—I'll echo the other remarks—thank you for being willing to come to East Tennessee. Welcome to East Tennessee. Ms. Lloyd, thank you so much for participating in this panel today.

And Zach, Zach and I have, we've come through some real battles together already and have a real comradeship. And I think Zach's just doing a super job for the Third District. And I think he knows we're going to have changes; I mean, we're all going to go through some changes in trying to balance the budget. And it's even more important than ever that we look forward; we don't want to react, we want to be proactive with these changes. And make sure that

universities and business and industry and government all work together, and I think this is what we're seeing right here. I think it's a wonderful, wonderful beginning.

My hat's off to Zach and all those folks on his staff, they've done a super job getting this together. Look forward to the very distinguished panel that you, Mr. Chairman, have gotten together today, look forward to hearing their testimony. I yield back the remainder of my time. [Audience applauds.]

Chairman STEVEN SCHIFF. Thank you very much. I'd now like to introduce our very distinguished panel. They are Dr. Neil Lane, who's Director of the National Science Foundation located in Arlington, Virginia; Dr. Martha Krebs, who is Director of the Office of Energy Research of the United States Department of Energy in Washington; Dr. Alvin Trivelpiece, Director of Oak Ridge National Laboratory; Dr. John McTague sitting in the third position, Vice-President of Technical Affairs of Ford Motor Credit Company—Ford Motor Company, excuse me. [Parties laugh.] There really is a Ford Motor Credit Corporation.

Dr. JOHN MCTAGUE. And it makes more money than the cars do.

Chairman STEVEN SCHIFF. Well, I guess I just gave away that I'm a lawyer, not a scientist. He's from Dearborn, Michigan. And once again, last but not least, Dr. Joseph Hamilton, Chairman of the Department of Physics and Astronomy at Vanderbilt University in Nashville, Tennessee.

You're all welcome. We have copies of your written statements, but I believe copies are available elsewhere in this room for people to take with them if they so desire. I would invite you to proceed, but try to encourage you to stay within, say about ten minutes if you're able to, so there's some time for questions back and forth. Dr. Lane, I'd like to begin with you, please.

TESTIMONY OF DR. NEAL LANE, DIRECTOR NATIONAL SCIENCE FOUNDATION, ARLINGTON, VA

Dr. NEAL LANE. Thank you, Chairman Schiff, members of the Committee, and the Tennessee Delegation, past and present. Thank you for inviting me to join you here today. It's always a pleasure to be in Tennessee, and it's always fun to talk about the National Science Foundation and some of its exciting activities, including some that are in partnership with the Oak Ridge National Laboratory. It certainly is one of these gems the Nation can be proud of.

The topic of today's hearing, "Long Term Science Strategy: A Thirty-Year Approach," is certainly timely. While most people realize that it can take a very long time for discoveries that result from basic research to be fully utilized, many do not appreciate the complex interplay of original ideas, new interpretations of old ideas, incorporation of isolated facts, false starts, unexpected breakthroughs and breakdowns, chance conversations, and applications of new technologies in unexpected ways that make the whole process work. It's a complex process, and often not as well understood as it ought to be.

Well, this can make it difficult to appreciate the value of long-term commitment to support research that may appear to have little immediate utility. But, ironically, it's just this difficulty in pre-

dicting when and how scientific discovery will pay off that makes a national commitment to government-supported research so important over the long term.

Parenthetically, an article emphasizing a growing emphasis on short-term research by industry appeared in the Wall Street Journal on May the 22nd under the heading "Top Labs Shift Research Goals to Fast Payoff." So I would ask, who's going to think about the Nation's future?

When we talk about the long-term, we're really referring to a comparatively small number of years. The National Science Foundation was established in 1950, five years after the close of the Second World War. And in its short institutional life, the NSF has played a critical role in helping America establish preeminence in science. Today, the NSF has an important responsibility for safeguarding and enhancing the Nation's future prosperity by supporting excellent research and education in every area of science and engineering.

Many leading economists and policy makers and policy researchers have recognized the importance of public investment in science and technology. Several key studies have indicated that these investments in science and technology yield very high rates of return to society. The activities supported by the NSF, namely fundamental research and education, are generally viewed as among the most productive of all Federal investments. And that certainly holds for the research activities of the other Federal agencies as well.

So, although fundamental research, by its very nature, is focused on the unanswered questions that defy our ability to predict outcomes, such research is often initiated and influenced by current practical problems. The historical example of the French scientist Pasteur is often used to illustrate this point. Pasteur responded to public health and commercial goals throughout his stellar career in microbiology. Both historical record and the current record substantiates the elegant interdependence in research for the quest of new knowledge, but also for pragmatic purposes.

There are numerous contemporary examples of research that is assuredly fundamental, but simultaneously holds promise to address very current problems. For example, Game Theory—the mathematical economic study of interdependence—has been considered abstract and arcane even by most economists. But recently, the assessment has changed. In 1994 NSF-funded university researchers won the Nobel Prize in Economics for their work on Game Theory.

And just last year, this theory began to pay big dividends when other leading economists originally funded by NSF designed the innovative FCC-sponsored auction of radio spectrum licenses that have netted billions of dollars to the U.S. Treasury.

Also, the study of one of Nature's greatest feats of engineering I like to talk about is the spider web. It may seem esoteric and fundamental, except, of course, to the spider. However, researchers have determined that the silk spun by these golden orb-weaving spiders possesses the strength of steel fibers, while also being stretchable. And the process by which the spider spins silk, unlikely as it may seem, holds promise for yielding environmentally-

benign manufacturing techniques for industrial fibers. This research spans the fields of biotechnology, materials, and manufacturing.

The very interrelatedness of scientific and engineering research underscores the need to relinquish the artificial barriers that may have hindered the natural connections between the fields of science and engineering. Often, the most exciting breakthroughs and unexpected discoveries come at points where disciplines overlap. Our ability as a Nation to take advantage of these breakthroughs in the future depends largely on whether we will have a healthy and vibrant scientific enterprise.

And this can only occur if there are world-class scientists in our National Laboratories and in our universities, with the freedom to ask new questions, investigate every path, and pose new ideas regardless of whether the research is driven by a utilitarian concern or by fundamental interest.

Eric Hoffer once noted that, "There can be no real freedom without the freedom to fail." Well, that can equally be said of science. I would maintain there can be no real science without the freedom to test new ideas and explore new frontiers that lead to the creation of new knowledge.

So how do we ensure that the discoveries and the breakthroughs and the new knowledge actually benefits society? Certainly that's one of the questions we will address today. We do know that those benefits flowing from the discovery of new knowledge do not occur as an automatic result of many talented people doing research. Almost thirty years ago Hendrik Bode, of the then Bell Telephone Laboratories, restated this, and I'll quote from him,

> It's not necessarily true that an increase of fundamental research, by itself, would lead to a significant increase in beneficial applications. The outcome would depend primarily on the overall structure. The primary problem confronting the country, then, is that of maintaining a scientific and technological establishment that works in a coherent and an effective way.

Well, the research enterprise, especially at our universities, which assures a continuity of that enterprise, is a critical component for this establishment. Nevertheless, the universities are only one leg of the science technology chair, and they cannot stabilize the chair on their own. The mission agencies, through their National Laboratories, and the various industry consortia all contribute to the effective and coherent working of the scientific and technological establishment.

Informed debate on public policy, high value jobs, competition in the global markets, and the education of current and future generations require that science be an integral part of the national fabric. Our universities and National Labs, like Oak Ridge, are important components in the process of making this happen through the creation of innovative partnerships with communities, with institutions outside the research environment. So, through these important partnerships, the new knowledge gained through the discovery process can reach those who seek to use and apply it, and the paybacks to society can be made more visible to the taxpayers who support most of this.

One obvious example of how research is connected to what some might call the real world, at least the world beyond the research

laboratory, is the natural connection between research and education of students in our universities and colleges. One of the strengths of the American system of higher education, widely acclaimed as the best in the world, has been the practice of research and teaching in the same place, by the same people.

This arrangement has capitalized on the natural connection, complementary connection, between the process of education and that of discovery. Each is enhanced and enriched by the other. From a certain perspective, they're the same; they're both about learning. This natural connection was demonstrated by a recent survey at the Oak Ridge Associated Universities, ORAU, when they conducted a poll among its sixty-five member colleges and universities on the subject of teaching and research.

I'll give you a few quotes from that survey. One professor said:

> It would appear to me that if one acknowledges that research is essentially teaching oneself while instruction is teaching others, then the interrelationship and symbiotic relationship between the two is inescapable.

A senior vice-president and provost said:

> The undergraduate program is at the very heart of all we do. It's our responsibility to integrate cutting-edge research and technology into undergraduate education, to infuse the international dimension and to develop the leadership skills of our students.

Well, at NSF we're committed to helping the universities foster these natural connections through a number of innovative programs designed to increase the participation of undergraduates in research. One of them, the Research Experiences for Undergraduates—or the REU program, as we call it—gives undergraduate students the chance to participate directly in research projects. On virtually every campus and every National Laboratory like Oak Ridge I visit around the country, I hear very strong statements about the success of this program and the importance of keeping it strong.

One other example of the impact can be seen here in Tennessee, where NSF has funded a program in Chemistry at the University of Tennessee at Knoxville, that has a close partnership with the researchers here at Oak Ridge. And that program actively involves undergraduate researchers. It's a natural connection, given Oak Ridge's research on waste remediation technologies that often center around innovations in chemistry and chemical engineering.

Oak Ridge researchers have had a tradition of outreach and partnerships with local universities and colleges which has greatly enhanced the NSF-sponsored research activities at those schools.

But Oak Ridge's educational outreach is only one example where the National Laboratories are leaders in forming innovative partnerships. Another good one—also involving NSF—is the National High Magnetic Field Laboratory, founded through an innovative partnership between the Foundation and Florida State University, the State of Florida, and Los Alamos National Laboratory.

Activities at Oak Ridge in High Performance Computing and Communications provide another very important example of partnerships with NSF and with industry as well. As one of the Department of Energy's premier High Performance Computing Centers, Oak Ridge is a leader in advanced computing research, aided by an important partnership with the Intel Corporation, in this case.

I should add that Oak Ridge's Director, Al Trivelpiece, has provided valuable insight and advice as a member of the NSF-funded Task Force advising us on the future of the NSF-supported Supercomputing Centers. We certainly appreciate him doing that for us.

And I think, as Martha Krebs will tell us in her testimony, the interaction between industry, universities, and National Labs is occurring through partnerships of the kind I've discussed. The challenge is to accelerate and enhance these interactions in order to continue the tradition of discovery in U.S. Science, and also to assure that the new knowledge and technologies that come from that science are put to use in service for society.

Science is not simply about the future. In a very real sense, it is our future. We surely can't forecast where and when discoveries will be made. Research, though, does provide a process and perspective which historically has produced new knowledge, and knowledge that has proven to be vital and useful in sustaining the Nation on a successful path. In this regard, science should be viewed not as a cost, but as an investment.

Mr. Chairman, as you and your colleagues deliberate future Federal support for research, I would urge you to recognize not only the complexity of the research undertaking I've talked about, but also the diversity and the interrelatedness. It seems appropriate here to mention the basic research activities in the social, behavioral, and economic sciences at NSF.

These areas of science have been an integral part of the NSF's portfolio since the 1950's, and are at the core of our mission to maintain the health of the Nation's science and engineering enterprise. The advances in Game Theory that I mentioned earlier show the fundamental nature, intellectual challenge, and the practical value of these important tools of science.

Finally, while both the House and Senate budget resolutions demonstrate continued strong support for the NSF in a very difficult budget environment, the research enterprise as a whole should not be viewed as a collection of isolated parts. Our ability as a Nation to maintain a leadership role in science and engineering research results from a diversity of approaches, broad support of our purpose, the successful coordination of strong programs of research across agencies, and integration of research and education.

There have been calls to increase the efficiency of Federally-supported research by eliminating or consolidating activities. While there's merit in having such a debate, it's important to consider the often overlooked benefits of the current system. The loss of the flexibility that we have under the current system could turn out to be a very high price to pay for what may be a modest gain in efficiency.

At NSF, less than five percent of our funding goes for agency salaries and expenses. Yet we continue to seek ways to improve our efficiency and provide the public with an even greater return on its investment as a part of the Federal reinventing-government policies. We need to continue to have the flexibility to do this.

Mr. Chairman, I would conclude by noting that every research discovery provides an opportunity for knowledge that can be

matched to a practical problem, it can be integrated within and across fields of study, and used as the starting point for new lines of inquiry. Each scientific discovery provides us with a clear understanding of our universe, of ourselves, and over time, provides us with options for improving the quality of all our lives, the lives of our children and of their children. Science is an investment that just keeps on paying.

Thank you very much for this opportunity to testify. I'd be pleased to participate in the question period.

[The prepared statement of Dr. Lane follows:]

REMARKS BY
DR. NEAL LANE
DIRECTOR, NATIONAL SCIENCE FOUNDATION
BEFORE THE
SUBCOMMITTEE ON BASIC RESEARCH
COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES
OAK RIDGE, TENNESSEE
JUNE 1, 1995

Chairman Schiff, members of the Committee and members of the Tennessee delegation, it is a pleasure to be in Tennessee today and I appreciate the opportunity to testify on behalf of the National Science Foundation. I am pleased to be here to discuss some of the excellent research activities and innovative partnerships occurring at Oak Ridge National Laboratory, one of the nation's premier research institutions.

The topic of today's hearing -- Long-term Science Strategy: A 30-Year Approach -- is certainly timely. While nearly everyone realizes that it often takes a long time for the discoveries that result from basic research to be developed into technology, many do not appreciate the complex interplay of original ideas, new interpretations of old ideas, incorporation of isolated facts, false starts, unexpected breakthroughs, chance conversations, and applications of new technologies in unexpected ways that make the whole process work.

This can make it difficult to appreciate the value of the long-term commitment of funds in areas of research that appear to have little immediate utility. But ironically, it is just this difficulty in predicting when and how a scientific discovery will pay off, that makes a national commitment to government-supported research so important over the long term. Parenthetically, an article emphasizing the growing emphasis on short-term research by industry appeared in the Wall Street Journal on May 22 under the headline "Top Labs Shift Research Goals To Fast Payoff." So who's going to think about the nation's future?

But when we talk about the long term, we are really referring to a comparatively small number of years. The NSF was established in 1950, 5 years after the close of the Second World War. In its short institutional life, the NSF has played a critical role in helping America establish preeminence in science. Today, the NSF has an important responsibility for safeguarding and enhancing the nation's scientific future by supporting excellent research in every area of science and engineering.

Many leading economists and policy researchers have recognized the importance of public investments in science and engineering. Several key studies have indicated that these investments in science and technology yield very high annual rates of return to society. The activities supported by the NSF -- namely fundamental research and education -- are generally viewed as among the most productive of all federal investments.

Although fundamental research, by its very nature, is focused on the unanswered questions that defy our ability to predict outcomes, that research is often initiated or

influenced by a current, practical problem. The historical example of the French scientist Pasteur is often used to illustrate this point. Pasteur responded to public health and commercial goals throughout his stellar career in microbiology. Both the historical record and the current record substantiate the elegant interdependence in research of the quest for new knowledge and pragmatic purposes.

There are numerous contemporary examples of research that is assuredly fundamental but simultaneously holds promise to address very current problems. For example, Game Theory -- the economic study of interdependence -- has been considered abstract and arcane even by most economists. Recently, that assessment has changed. In 1994, NSF-funded university researchers won the Nobel Prize for economics for their work in game theory. And just last year, the study of game theory began to pay big dividends when leading game theorists -- originally funded by NSF -- designed the innovative FCC-sponsored auction of radio spectrum licenses that have netted billions of dollars to the U.S. Treasury.

Also, the study of one of nature's greatest feats of engineering, the spider web, may seem to be esoteric and fundamental. However, researchers have determined that the silk spun by the golden orb-weaving spider possesses the strength of steel fibers while also being stretchable. The process by which a spider spins silk, unlikely as it may seem, holds promise of yielding environmentally-benign manufacturing techniques for industrial fibers. This research spans the fields of biotechnology, materials, and manufacturing.

The interrelatedness of all scientific and engineering research underscores the need to relinquish artificial barriers that may have hindered the natural connections between the fields of science. Often, the most exciting breakthroughs and unexpected discoveries come at the points where disciplines overlap.

Our ability as a nation to take advantage of these exciting breakthroughs in the future depends largely on whether we will have a healthy and vibrant scientific enterprise. This can only occur if there are world-class scientists in our national laboratories and our universities with the freedom to ask new questions, investigate every path and pose new ideas regardless of whether their research is driven by a utilitarian concern or not. Eric Hoffer once noted that: "there can be no real freedom without freedom to fail." Well, that can equally be said of science. I would maintain that there can be no real SCIENCE without the freedom to test new ideas and to explore new frontiers that lead to the creation of new knowledge.

How do we ensure that the discoveries, breakthroughs and new knowledge actually benefit our society? Certainly that is one of the questions we will address today.

We do know that those benefits flowing from the discovery of new knowledge do not occur as an automatic result of many talented people doing research. Almost 30 years ago, Hendrik Bode, of the then Bell Telephone Laboratories, restated this by writing, (quote) "It is not necessarily true that an increase of [fundamental] research by itself would lead to a significant increase in...beneficial applications. The outcome would depend primarily on the overall structure. The primary problem confronting the country, then, is that of maintaining a scientific and technological establishment that works in a coherent and effective way." (end quote)

The research enterprise, especially at our universities, is a critical component in that establishment. Nevertheless, it is only one leg of the chair, and cannot make the chair stand firm and stable by itself. The mission agencies, the National Laboratories, the technology centers, and the various industry consortia all contribute to the effective and coherent working of a scientific and technological establishment.

Informed debate on public policy, high value jobs, competition in global markets, and the education of current and future generations require that science be an integral part of our national fabric. Our universities and national labs like Oak Ridge are important components in the process of making this happen though the creation of innovative partnerships with institutions outside the research environment. Through these important partnerships, the new knowledge gained through the discovery process can reach those who seek to use and apply it.

One example of how research is connected with what some call the "real world" [or at least the world beyond the research laboratory] is the natural connection between research and the education of students at our universities. One of the strengths of the "American" system of higher education, widely acclaimed as the best in the world, has been that the practice of research and teaching in the same place by the same people has capitalized on the natural and complementary connections between the process of education and that of discovery. Each is enhanced and enriched by the other. From a certain perspective, they are the same: they are both about learning.

This natural connection was demonstrated by a recent survey by Oak Ridge Associated Universities conducted among its 65 member colleges and universities on the subject of teaching and research.

One professor said, (quote) "It would appear to me that if one...acknowledges that research is essentially teaching oneself, while instruction is teaching others, the interrelationship and symbiotic relationship between the two is inescapable." (end quote)

A senior vice-president and provost said, (quote) "The undergraduate program is at the very heart of all that we do. ... It is our responsibility to integrate cutting-edge research and technology into undergraduate education, to infuse the international dimension, and to develop the leadership skills of our students." (end quote)

At NSF we are committed to helping universities foster these natural connections through a number of innovative programs designed to increase the participation of undergraduates in research. One of them, the Research Experiences for Undergraduates (commonly known as the REU) program, gives undergraduate students the chance to participate directly in research projects. On virtually every campus and at National Laboratories like Oak Ridge that I have visited, I hear very strong statements about the successes of this program and the importance of keeping it strong. So it seems that we are having some impact.

One example of this impact can be seen here in Tennessee. NSF has funded an REU program in Chemistry at the University of Tennessee at Knoxville that has had a close partnership with the researchers here at Oak Ridge. This is a natural

connection given Oak Ridge's research on waste remediation technologies that often center around innovations in chemistry and chemical engineering. Oak Ridge researchers also have had a tradition of outreach and partnerships with local universities and colleges which have greatly enhanced the NSF-sponsored research activities at those schools.

These partnerships with universities and industry are crucial for the success of the National Laboratories. But Oak Ridge's educational outreach are only one area where the National Laboratories are leaders in forming these innovative partnerships. One of the best examples that also involves NSF can be seen in at the National High Magnetic Field Laboratory, founded through an innovative partnership between NSF, Florida State University, the State of Florida and Los Alamos National Laboratory. Also, Oak Ridge's activities in High Performance Computing and Communications are also very important examples of partnerhsips with NSF and with industry as well. As one of the Department of Energy's premier High Performance Computing Centers, Oak Ridge is leader in advanced computing research aided by an important partnership with the Intel Corporation. Oak Ridge's Director, Al Trivelpiece, has also provided important insight and advice as a member of an NSF-sponsored Task Force on the Future of the NSF-University Supercomputing Centers.

So, as Martha Krebs has also discussed in her testimony, the interaction between industry, universities and the National Labs is occurring. What we need to think about is how we can accelerate and enhance these interactions in order to continue the fine history of discovery at the National Labs.

The process of discovery is integral to progress -- our world is very much predicated on and powered by science and technology. Anyone who has gone through the checkout line in the supermarket can testify to that. Thus we must not hold science separate and autonomous from our everyday lives. Our nation, indeed every society, has real needs and problems. Science must toil in those trenches as a partner in finding solutions.

We all know that science is not simply about the future. Rather, it is the future. While we surely cannot forecast where and when discoveries will be made, research provides a process and a perspective which historically has produced new knowledge -- knowledge that has proven to be vital and diversely useful to sustaining this nation on a successful path.

Mr. Chairman, as you and your colleagues deliberate future Federal support for research, I would urge you to recognize not only the complexity of the research undertaking, but also its interrelatedness. It seems appropriate here to mention the importance of the basic research activities in the social, behavioral sciences at the National Science Foundation. These areas of science have been an integral part of the portfolio of research that we have funded since the 1950's and are important to our mission to maintain the health of the Nation's science and engineering enterprise. These disciplines have contributed significant advances in research, as exemplified by the dramatic payoff gained by the advances in game theory that I have mentioned.

While both the House and Senate budget resolutions demonstrate continued strong support for NSF in a very difficult budget environment, the research enterprise cannot

be viewed in isolation. Our ability as a nation to maintain a leadership role in science and engineering research results from a diversity of approaches, broad support of our purpose, and successful coordination of research across agencies, and the integration of research and education.

There have been calls to increase the efficiency of Federally supported research by eliminating or consolidating activities. While there is merit in having this debate, it is important to consider the often overlooked benefits of the current non-centralized system. The loss of the flexibility that we have under the current system could be turn out to be too high a price to pay for what may be a very modest gain in efficiency. At NSF, less than five percent of NSF funding goes for agency salaries and expenses, yet we continue to seek ways to improve our efficiency and to provide the public with an even greater return on its investment.

Mr. Chairman, I would conclude by noting that there is no such thing as useless scientific knowledge. Every research discovery provides information that can be matched to a practical problem, integrated within and across fields of study, and used as the starting point for new lines of inquiries. Each discovery provides us with a clearer understanding our universe and ourselves, and over time, provides us with options for improving the quality of our lives.

Thank you for this opportunity to testify, and I would be pleased to respond to any questions that you might have.

Chairman STEVEN SCHIFF. Thank you, Dr. Lane. Dr. Krebs.

TESTIMONY OF DR. MARTHA KREBS, DIRECTOR, OFFICE OF ENERGY RESEARCH, DOE, WASHINGTON, DC

Dr. MARTHA KREBS. Mr. Chairman, members of the Subcommittee, also my fellow witnesses, on behalf of the Department of Energy, I'd like to take the opportunity to thank you for bringing the Subcommittee and for coming to Oak Ridge today, because we at DOE see Oak Ridge, the contractors here, the Laboratory, and the community as a very important part of the Department of Energy. And one that has had a history of continuous contributions to DOE missions, from the national security mission, to energy, to science and technology.

And I wanted to particularly say how important I think it is for members to visit these kinds of facilities, and to learn firsthand what they bring to the science and technology enterprise of the Nation.

This afternoon I'd like to talk about, first of all, this issue of long-term science and technology strategy, DOE's role in that strategy, the assets, the science and technology assets that are represented by DOE's National Laboratories. And I would like then to comment on the need for maintaining bipartisan support for science and technology as we go forward in what I think we all believe is a bipartisan effort to reduce the deficit for this country.

First of all, let me talk about the science and technology strategy issues. Fifty years ago, Vannevar Bush reported to President Truman in his document called *Science, The Endless Frontier.* And after World War II and the clear benefits that science and technology, and scientists and engineers could bring to the war effort, it became clear that it was important to maintain that capability. And *Science, The Endless Frontier* was a vision of benefits that scientists and engineers could bring to this country.

And in the ensuing half century, what we have seen and has been, in fact, validated by various studies, that science and technology investments by the Government and by the private sector, have brought at least a fifty-percent annual rate of return to this economy, and to our country, and to the people who benefit from that science and engineering.

What we have also seen is that we're now at the end of the Cold War, that there has been, as Dr. Lane noted, a decline in corporate R&D. So there has been a need for a revisitation of what is and should be science and technology policy in this country.

I believe that the Clinton Administration, from the very beginning, recognized the need to articulate a new science and technology policy; not just a science policy, but also a technology policy. Within days after his inauguration, the President released "Technology, Engine of American Growth." And it, too, was a vision. It was a vision for world-class science, math, and engineering, a vision of economic growth and environmental stewardship, and effective government. Which, in large measure, for those of us who are in the middle of it, we are re-engineering, downsizing, and learning how to do more, or at least the same, with less.

And in a further articulation of what that meant for science, in late 1994, the President released a policy statement that was prob-

ably the first by a president in perhaps more than twenty years, and that was *Science in the National Interest,* in which, he laid out goals for the science establishment that related not only to the pursuit of fundamental understanding, but also to a connection between basic and applied research in support of national missions and national goals.

Within the Department of Energy, we see ourselves as major players in that science and technology policy, not only in the context that the President has set out, but in the longer term context that we are all invested in. Within the Department of Energy and our seventeen-and-a-half-billion-dollar budget, six-point-six billion is considered for research and development, more than forty percent.

But when you think about our total budget, the remainder of the seventeen-point-five billion that's invested in national security, in environmental cleanup, in energy, and in science and technology; generally we are driven—all of that investment is driven—by the contributions that we make in science and technology. We could not pursue our national-security requirements without a close connection between basic science, physics, and chemistry, and the more practical applications that are involved in engineering and systems development.

Similarly, energy is an activity; a set of technologies that requires us not only to have fundamental understanding, but also to understand and to develop applications from those fundamental understandings. At times, the applications, the problems drive the need for understanding. And so, within the Department of Energy, we see ourselves as needing to invest in science and technology, in basic and applied science, in things that meet near-term needs, in our weapons and our cleanup, and even at times in the energy technology programs, but also which are driven and require a long-term investment in fundamental science.

We are, as I indicated, a major player in basic research. We provide, in addition to ninety percent of the investment in high-energy nuclear physics, we have about one-point-seven billion dollars in activities that provide the knowledge and skill base, the human and physical infrastructure for DOE's energy and environmental issues. This is problem-focused science, from material science, chemical science, geosciences, human genome, nuclear medicine—all of these are driven by the opportunities and the needs associated with either producing and using energy or understanding the health and environmental consequences of energy.

They are intrinsically multi-disciplinary. And from the beginning, because we start with practical problems, we need to bring many disciplines together.

We are collaborative; we manage our programs from the beginning in a collaborative way that reaches across institutional as well as disciplinary lines. We make our investments in universities, in national laboratories, and in industry. We manage our programs so that these institutions talk to each other. We manage across lines within the Department of Energy. We cooperate and collaborate with our colleagues in our technology programs. We find our problems in our technology programs. We find our technologies in our customers in the energy industries.

And we work with other agencies. As Neil Lane indicated, we have collaborative programs with the National Science Foundation. The human genome program is an intrinsically interagency, as is our efforts in global climate research.

Let me turn now to the Laboratory system. As you know, I spent the last ten years before I joined the Department of Energy in a DOE National Laboratory. I believe, not only from my head but also from my heart, because of the people that I have had and have had the opportunity to deal with, that these laboratories are, indeed, critical elements of the national science and technology infrastructure, that they represent assets not only to the Department of Energy, but also to the broad science and technology effort of this country.

They are a set of tremendous people who have the capability to build and operate facilities that not only benefit the Department of Energy, but also the national science effort. Examples: Dr. Lane spoke about the advanced computing facility that is pursuing the development of massively parallel computing. That benefits not only the Department of Energy's effort to understand energy technologies, but also brings in users from the scientific, university community, and industry community.

The single-purpose laboratory, such as Fermi Lab and the Stanford Linear Accelerator Center in California, have pursued a course—and, most recently, of course, we discovered and finally determined that, indeed, we had discovered the top core. When I told the Secretary that, indeed, we had discovered the top core, she said to me, "Martha, what is this good for?" And I said to her, I said, "Madam Secretary, I don't know yet."

But what I do know is that sixty or seventy years ago we didn't know that there were protons; we certainly didn't know what they were good for. But now, we treat cancers, and we use them, for example, to produce neutrons that help us, in fact, understand materials. So we can't predict always what will come from fundamental science, but what we have is a set of examples and instances where, clearly, there has been payoff for humanity.

There are many other examples that I could give you but I'm not going to dwell on them for the Department as a whole. But, clearly, here at Oak Ridge I think there is an excellent set of examples of how these Laboratories work together with the other members of the county to provide benefits for our society.

Before the hearing began, we heard from Dr. Shull about neutron scattering, and one of the things that made me think about was that here was an example of technology that had been developed for the national security of this country, and that was available and ready to be turned to asking some very fundamental questions that could not have been asked without the technology that had been otherwise developed.

And as a consequence of asking fundamental questions, we were subsequently able to develop and build here the High-Flux Isotope Reactor, HFIR, which has become an invaluable tool for science and for technical applications in collaboration with many members of the industrial community.

The Oak Ridge National Laboratory took that capability and materials characterization and applications a step further when they

proposed—and the Department of Energy built—the High-Temperature Materials Laboratory, which offers an opportunity for collaboration between my basic science programs and the energy efficiency programs, and, once again, provides an opportunity for collaboration with university and industry to develop new devices and materials for use in energy-efficient technologies.

Finally, I'd like to note Liane Russell's contribution. It was made possible here at Oak Ridge, and for which she won the 1994 Fermi Award. And her understanding of mammalian genetics laid the foundation for our contributions within the Department and our understanding that allowed us to be a contributor to the human genome program.

These are the kinds of things that happen at National Laboratories, and that, in some respects, don't happen in universities. Because we can bring to bear in these institutions the people, with their various interests and capabilities, motivated by the problems that have national importance. And moving from that base, we can make contributions that go far beyond just the national positions that we started from.

And what's important to me is that we not lose that capability. For me, I believe that the benefits of the fifty-year partnership that was envisioned by Vannevar Bush are obvious in places like Albuquerque, New Mexico, and Berkeley, California, and Hanford, Washington. These institutions have brought to bear a way of doing science that is important for us not to lose, especially in this time of budget reductions.

We in the Department of Energy understand the need to balance the budget. We proposed—I should say, indeed, the Secretary and the President have proposed—a way to obtain fourteen-point-one billion dollars in reductions over the next five years. I personally, as a manager within the Department of Energy, am challenged to meet those goals. But I am concerned, as we move towards these deficit reductions, that we not engage in an ideological view of government downsizing.

I am concerned that there may be a misunderstanding of DOE's responsibilities and contributions to science and technology, both near- and long-term. And that in an unthinking way, we may turn back the clock, especially in science and technology. Especially in science, you may break a system that is the envy of the world.

In *Science in the National Interest,* the document I referred to earlier, there's a quote that goes:

> The Nation's R&D investment has yielded a scientific enterprise without peer, whether measured in terms of discoveries, citations, awards and prizes, advanced education, or contributions to industrial and informational innovation. Our scientific strength is a treasure which we must sustain and build on for the future.

We welcome the Subcommittees' focus on these issues. It takes vision and courage to maintain the long-term focus and commitment that's represented by the Department's assets, especially in laboratories. We look forward to working with you. I look forward to working with you, and your colleagues, to support the Federal—and the DOE—science-and-technology engine that has benefited our Nation, this community, and all the individual citizens of this country. Thank you.

[The prepared statement of Dr. Krebs follows:]

STATEMENT OF

DR. MARTHA KREBS

DIRECTOR OF ENERGY RESEARCH

DEPARTMENT OF ENERGY

BEFORE THE

COMMITTEE ON SCIENCE

SUBCOMMITTEE ON BASIC RESEARCH

UNITED STATES HOUSE OF REPRESENTATIVES

JUNE 1, 1995

Mr. Chairman and Members of the Subcommittee.

I am pleased to be here today to discuss federal support for science and technology. I appreciate the broad scope of your hearing charter, and particularly welcome your decision to hold this hearing at the Department of Energy's (DOE's) Oak Ridge National Laboratory. The timing of this hearing is extremely important as well, given the major decisions being made within the Congress on ways of reducing the federal budget deficit--including through major cutbacks in certain areas of federal research and development (R&D).

The title of this hearing makes clear that the Subcommittee's overriding interest is with the development of a long-term national science strategy. At the outset, I will express my firm view that one cannot develop a science strategy in isolation from technology. Although it seems to be in vogue these days to describe science and technology as separate and distinct activities--with sharp dividing lines between them--I believe this is a wholly inaccurate view of the R&D enterprise. Science and technology, research and development, these are inextricably linked parts of the process of discovery, innovation, and application. I will emphasize this point throughout my testimony, which is organized in four general parts.

First, I will address the need to support the President's national science and technology policy. Second, I will provide a general overview of the Department of Energy's R&D program within the context of total federal R&D spending. Third, I will briefly review highlights of the Department's laboratory system, which represents a major asset within the Federal

Government's R&D infrastructure. Finally, I will address concerns that I have regarding possible congressional action that would jeopardize important National R&D programs--both here at Oak Ridge National Laboratory and elsewhere--that are aimed at advancing scientific understanding and accelerating the development of energy and environmental technologies.

TOWARD A NATIONAL SCIENCE AND TECHNOLOGY STRATEGY

Development of a long-term national science and technology strategy is an extremely worthy objective. I emphasize the adjective long-term, because advances in research and development--particularly in basic science--involve long time horizons. Stability both in the funding and policy framework for such research is enormously important for the efficiency and effectiveness of the work.

During the past 50 years--at least from the end of World War II through the end of the Cold War--the nation has had a fairly stable, long-term science policy. The intellectual foundation for that strategy was provided in the landmark 1945 report by Vannevar Bush to President Truman--Science the Endless Frontier. That report, and its compelling justification for strong federal support for research and development, helped establish the United States as the world's leader across virtually all fields of science and technology.

It is no understatement to say that science and technology have defined our place in history in the 20th Century, helping us win the Cold War, conquer many forms of disease, improve our quality of life, and greatly expand the

U.S. economy. The payoff for our investments has been enormous. Many economic studies have shown that federal investments in science and technology have brought, on average, a 50 percent rate of return to U.S. society.

The framework for U.S. science policy in the past, however, is not likely to govern the future. With the dissolution of the Soviet Union and growing concern with federal budget deficits, it has become clear that federal R&D spending patterns will change. They already are changing. Corporate investments in long-term, basic research has declined considerably; university R&D faces new pressures; and federal R&D may be on the brink of an historic decline.

Since taking office, President Clinton has had a clear view of the importance of science and technology policy within the larger goals of government. Within days of his inauguration, Technology, the Engine of Growth was published. The framework established by the President saw science and technology as a continuum with multiple opportunities for feedback and interaction throughout the process. Building upon a firm base of fundamental science, federal investment in both science and technology were aimed at benefits for national missions, for improved government services, and for the American people. The distinctions between basic and applied science or between science and technology became less important. What remained critical was the continued commitment to benefits in the long-term.

In late 1993, the Clinton Administration continued its rearticulation of science policy. Under the leadership of the President's Science Advisor,

Jack Gibbons, a major new policy document was developed with the active involvement of hundreds of leading scientists from throughout the nation. Science in the National Interest, released in August 1994, provides a compelling justification for continued strong federal R&D. As stated in that report:

> "The nation's [R&D] investment has yielded a scientific enterprise without peer, whether measured in terms of discoveries, citations, awards and prizes, advanced education, or contributions to industrial and informational innovation. Our scientific strength is a treasure which we must sustain and build on for the future."

This powerful observation provides a useful guide to the Subcommittee as it thinks about a science and technology strategy for the next century. At present, the United States has a scientific and technological enterprise that is the envy of the world. I recognize that the mood in Congress is to radically reform and to revolutionize government institutions and funding patterns. However, in the name of change and deficit reduction we must be cautious not to fix things that aren't broken, or endanger our ability to generate future wealth and improved quality of life once our deficit is in balance.

DEPARTMENT OF ENERGY: A MAJOR PLAYER IN FEDERAL R&D

This Committee is well familiar with the extent to which the Department of Energy has been a major investor in science and technology for the benefit of

the Nation. Historically, the Department's responsibility for nuclear deterrence and now stewardship for the nuclear stockpile has been delivered through the support of fundamental physics and chemistry combined with engineering and systems management. Our mission for environmental cleanup can only be delivered through the development of state-of-the-art technologies based on fundamental discoveries about the behavior of contaminants. Our energy mission is equally challenging, in that it requires marshalling of the science and technology that underlies future energy technologies as well as their consequences for the environment and human health. It also depends on achieving an appropriate balance and coordination of the federal investment with the private investment.

In the realm of Federal agencies that support science and technology, the Department of Energy is one of the largest. Our diversified R&D budget provides federal support for scientists and engineers throughout the nation. The Department's total R&D budget for Fiscal Year 1995 is $6.6 billion, amounting to nearly 40 percent of the Department's overall Fiscal Year 1995 budget of $17.5 billion, and nearly 10 percent of the total federal R&D budget of $72 billion. In the area for which I am responsible, the Department's $2.8 billion funding of basic research places it second to only the National Institutes of Health (NIH) in terms of support for fundamental exploratory research. The National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), and the Department of Defense rank third through fifth respectively.

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We are the historical sponsors of research in high energy and nuclear physics, providing 90 percent of the support. Through our investments in materials and chemical sciences, in geosciences, in structural biology, in atmospheric physics and chemistry, in human genomics, the Office of Energy Research provides the knowledge and skill base and the human and physical infrastructure for the Department's energy and environmental missions. This energy and environmental problem-focus informs our investments in universities, National Laboratories and industry. The Department's research program supports over 2300 university R&D grants totaling more than $600 million annually at more than 100 U.S. universities. These grants support more than 7,000 principle investigators. Wherever we invest, we manage our programs to enhance collaboration and communication across institutions and disciplines. Joint investments with our colleagues in the Department's technology programs and with other agencies such as NSF and NIH are critical elements of our approach.

A nearly unique aspect of the Department's investments in fundamental science has been its support for large-scale user facilities at its National Laboratories. These facilities are another manifestation of the Department's commitment to collaborative research. Driven by opportunities for new knowledge that supports the Department's missions, these facilities support more than 15,000 users, predominantly in the universities, and are often supported by sponsors other than the Department of Energy. These facilities are a critical element of the Nation's physical infrastructure for science that has kept us at the forefront of international science.

The contribution of these facilities has been recognized by the inclusion of a $100 million increase in the Fiscal Year 1996 budget request. The number of researchers at these facilities has grown by nearly 50 percent during the past five years, yet the Department must turn away large numbers of highly meritorious research proposals each year. The Science Facilities Initiative would enable thousands of additional researchers to perform their work on the major DOE user facilities.

THE DOE LABORATORY SYSTEM: A UNIQUE NATIONAL ASSET

The Department of Energy manages the largest laboratory system of its kind in the world. With origins in the Manhattan Project, the DOE laboratories have evolved during the past 50 years to become a major component of the Nation's infrastructure for maintaining U.S. leadership in scientific discovery and knowledge generation. Programs conducted at the Laboratories have consistently challenged our basic understanding of the world around us and driven new fields of scientific inquiry and technology development.

The Department operates 29 laboratories, ranging from large multi-program laboratories such as Sandia National Laboratory, Oak Ridge National Laboratory, and Brookhaven National Laboratory, to smaller, single program laboratories such as the Fermi National Accelerator Laboratory and the Stanford Linear Accelerator Laboratory. The DOE laboratory system supports more than 25,000 scientists, engineers, and other technical staff. The Nation has invested more than $100 billion in these laboratories during the past 50 years to make them the world-class facilities that they are.

The DOE laboratories are helping develop solutions to National scientific challenges in areas such as: enhanced environmental quality through clean energy sources and pollution-prevention technologies; enhanced security through continued reductions in the nuclear threat; continued leadership across the frontiers of scientific knowledge; and a growing economy fueled by technology innovations that enhance U.S. industrial competitiveness and create high-skill, high-wage jobs for American workers.

The most valuable assets that the DOE laboratories have brought to their mission assignments in the past--and that will be dedicated to future missions--are their human and physical resources. These assets are characterized by interdisciplinary teams with the skills to tackle national problems of great complexity and scope, and sophisticated and often unique scientific facilities that enable researchers to explore new scientific frontiers, to model and simulate processes and solutions to problems, and to achieve new understandings of how the world works and how technology can better address national needs. These resources have helped train generations of scientists and technologists who have carried the capabilities of the laboratories to industry and academia.

By virtue of several decades of investment by the Nation in the DOE laboratories, these institutions currently exhibit a combination of physical and human R&D assets not duplicated anywhere in the world. The replacement value of the physical R&D assets at these laboratories exceeds $30 billion, and includes facilities such as:

- One of the world's premier assemblages of high-performance computing centers, including many of the world's most powerful scientific computers, which serve as a fundamental tool for helping meet essentially all of the missions of the laboratories and which are setting the stage for broad use of massively-parallel computers in the future;

- Two of the world's most powerful particle accelerators, which are being used to discern the fundamental building blocks of nature;

- Three of the Nation's most sophisticated facilities for mapping the human genome;

- Two of the world's most powerful neutron sources, which provide the means for materials characterization, medical isotope production, and environmental analysis;

- One of the world's leading tokamak reactors for studying fusion plasmas, which has produced the most power ever in controlled fusion energy experiments;

- Three of the world's premier x-ray radiation sources, which are being tapped for materials research in areas ranging from structural biology to designing integrated circuits to developing new industrial chemicals; and

- Major and unique facilities for studying combustion, solar thermal generation of electricity, photovoltaic cells, energy efficient lighting and window systems, nuclear reactor safety, energy utilization for construction materials and building technologies, and semiconductor reliability.

The Department operates 26 major R&D user facilities, which are used by more than 15,000 scientists each year from institutions located in all 50 states, including 353 colleges and universities and 245 U.S. companies. In the State of Tennessee alone, there are more than 20 companies and eight colleges and universities that use DOE user facilities.

I will provide some specific examples to indicate how this works out right here in Oak Ridge. Clifford Shull is here today. His pioneering work at the Graphite Reactor revealed the phenomenon of neutron scattering and won him the Nobel Prize in Physics for 1994. It also laid the foundation for neutron scattering as a powerful tool for both fundamental knowledge and routine industrial applications. Today the High Flux Isotope Reactor serves hundreds of users from universities and industries interested in exploring the structure and dynamics of matter. This versatile facility has had impacts ranging from the development of new polymer blends in industrial products to the production of medical isotopes.

In addition, the Laboratory also operates ShaRE (Shared Equipment Research Program), which provides U.S. users access to state-of-the-art microanalytical facilities for materials science studies. Over 300 external users have

participated in this program. The consequences have been profound for our understanding of the properties and processing of new materials, ranging from metals, ceramics, and polymers.

The High Temperature Materials Laboratory here is another example of how the Department through its investments in the National Laboratories brings the results of fundamental science into the next generation of technology. The basic properties of metal aluminides were discovered and explored here at Oak Ridge. Through joint investments by the Office of Energy Efficiency and Renewable Energy, the Office of Energy Research, and industry, Oak Ridge has carried out collaborative research that has seen these versatile materials used in products ranging from turbine rotors to medical products. Once again this is an example of the kind of cross-institutional and cross-disciplinary collaborations that are at the heart of DOE's investment in science and technology.

But there is more. Advances in "massively parallel" supercomputing have enabled scientists at the Oak Ridge National Laboratory, in conjunction with colleagues at the Sandia National Laboratory and the Ford Motor Company, to develop an automotive crash simulator that does in 6 hours what once took 48 hours to do on a conventional supercomputer. Such work presages a whole new approach to a wide range of important, but until now, intractable commercial applications, like weather prediction and oil and gas exploration.

The laboratory has also played an important role in the Department's efforts to understand the consequences of energy production and use on health and the

environment. Liane Russell won the 1994 Fermi Award for her work at Oak Ridge National Laboratory on the genetic effects of radiation. This research led the world to a fuller understanding of the genetic structure of mammals and has been one of the foundation stones of the human genome program. Once again, it becomes clear how the basic science investment in unique facilities and scientific teams at the laboratories enables them to address the broad cross-disciplinary problems of interest to industry and the Nation.

The research environment within these facilities demonstrate strong interrelations between basic and applied research, and between government and private sector researchers. Clean lines of separation between science and technology cannot be made; each contributes to the other. The same holds for the relationship between laboratory scientists and those from the private sector, where each is contributing to the goals of the other.

BALANCING THE BUDGET WHILE SUSTAINING SCIENCE

The Nation faces a daunting challenge in its efforts to reduce the federal budget deficit. The Department of Energy has made a substantial contribution toward this goal through its plan to generate $14.1 billion in deficit reduction over the next five years through: the privatization of functions which more properly belong in the private sector, such as the Naval Petroleum Reserves and three Power Marketing Administrations (deficit reduction of $5.3 billion); major restructuring of the Environmental Management program (deficit reduction of $4.4 billion); reducing the cost of doing business at the DOE laboratories through implementation of recommendations from the Galvin

Task Force Report on Alternative Futures for the DOE National Laboratories ($1.4 billion); reductions in the DOE applied energy R&D programs ($1.2 billion); sale of highly enriched uranium ($0.4 billion); and strategic alignment of the Department ($1.7 billion).

The Department's strategy is to reduce overhead and administrative costs to the extent possible in order to protect funding for our vital national missions in national security, energy, science and technology, and environmental cleanup. Our commitment to reduce DOE employment by 3,788 personnel (27 percent) over the next five years--announced on May 3, 1995, as part of our Strategic Alignment and Downsizing Initiative--demonstrates that we are willing to make substantial cuts in the apparatus of the Department rather than to cut deeply into our R&D accounts. Recent actions within the Congress, however, suggest that valuable R&D programs throughout the Nation may soon be in jeopardy.

The Fiscal Year 1996 Budget Resolution adopted by the U.S. House of Representatives on May 18, 1995, included recommendations which, if enacted in subsequent Authorization and Appropriations bills, would cut $7 billion from the Department's R&D programs over the next five years. The cuts would be particularly severe in applied R&D in the areas of energy efficiency, which could be cut by as much as 80 percent, and fossil energy, which would be cut by 77 percent. The Department's renewable energy, fusion energy, basic energy sciences, and biological and environmental research programs would also be reduced by about 35 percent. The result could be the termination of contracts and research grants which the Department has with thousands of researchers

around the Nation located in industry, academia, and DOE laboratories (including Oak Ridge National Laboratory).

The programs hardest hit by the House Budget Resolution are those involving industrial partners and those which support applied research and technology development. The underlying philosophy appears to be that the government should stop supporting R&D that might be commercially-relevant, on the grounds that such work will be done by the private sector. In the private sector, however, companies currently are devoting some 80 to 90 percent of their R&D resources to short-term product development and process improvements. There exists a significant and growing gap in the innovation process, for which government-industry partnerships play a vital role. Oak Ridge and other DOE laboratories have made significant progress in recent years in developing R&D partnerships with the private sector that are helping accelerate the development of high-risk technologies. Such efforts may be in serious jeopardy as a result of congressional actions on the Fiscal Year 1996 budget.

CONCLUSION

Mr. Chairman, the United States has built and sustained a scientific enterprise that literally is unrivaled in the world. Although the direction and potential benefits of science funding are not always predictable, history teaches us that our investments in science have delivered huge returns. Questions about the proper role of government are central to the current debate over how to reduce the federal budget deficit. Regarding science and

technology, it is wrong to think that these are separable. Science and technology--discovery; innovation; use--are inextricably linked, with each contributing to the advance of the other. Similarly, researchers within academia, national laboratories, and industry must be interconnected. The Nation has benefitted substantially through enhanced integration of R&D performers from the public and private sectors. In many other nations, there is virtually no debate over R&D programs that facilitate partnerships between the government and the private sector. In the process of balancing the federal budget, we must be extremely careful not to jeopardize R&D investments that will sustain U.S. leadership in the next century. We welcome your Subcommittee's focus on a long-term national science strategy. The Clinton Administration has made important contributions toward the establishment of such a strategy. We look forward to working with you as you continue to examine these issues.

Chairman STEVEN SCHIFF. Thank you very much, Dr. Krebs. Dr. McTague, please.

TESTIMONY OF DR. JOHN McTAGUE, VICE PRESIDENT, TECHNICAL AFFAIRS, FORD MOTOR COMPANY, DEARBORN, MICHIGAN

Dr. JOHN MCTAGUE. Mr. Chairman, members of the Subcommittee, I'm very pleased to be able to participate with you here today. I was also pleased by the Chairman's opening remarks that we take the reduction in the deficit over the next several years as a given. I think along with that given, we also should take a commitment to avoid such deficits in the long-term as part of our given.

It seems to me that in this day and age, no one would deny that science and technology are integral to the strength of our economy and should play a significant role in addressing the avoidance of deficits in the long run. That's easy to come up with; the hard part is to come up with a strategy, a set of principals that will maximize the DOE's science and technology for the national goals.

What should the Federal Government do? Equally important, what should it not do? Whether our comparative advantages, and we've heard some of those with respect to basic research, what are we doing well, what not so well? What should we strengthen, and how? And what should we eliminate? Where should Government lead? Where should it be a partner and where should it get out of the way?

As you address these issues, I'd like to give you some of my own observations based on having been a university professor, having been a user of National Laboratory research facilities, and having been a director of a facility, of a National Laboratory research facility, and as Vice-President of Technical Affairs of a major automotive and credit company. [Parties laugh.] But, perhaps of more relevance to today is the time that I spent as a Deputy Director and as Active Director of the Office of Science and Technology Policy during both terms of the Reagan Presidency.

I see a lot of parallel between the evolution of the Reagan science and technology policy in the '80's and today's debates and actions, so it might be worth looking back at what was done and why, and whether the lessons bear the test of time.

Some of the choices were easy and were made early, some involved the Federal Government getting out of the way, and some called for solid support. For example, markets, stored and commercial demonstration projects such as coal gassification, shale oil, were ruled out. In today's language, I supposed they would be labeled as corporate welfare that involved the Government in attempting to pick and to subsidize the near-term commercial technologies.

Another easy one was Federal support for energy and basic research. There were many statements as to why the Government did this, but let me give you an example out of the Federal Budget Statement for 1986 that the President submitted to the Congress:

> The 1986 budget continues this Administration's emphasis on the importance of support for basic research, plus all scientific disciplines, even in a time of budget restraints. Scientific knowledge in fields such as mathematics, physics, chemistry, biology, and the various engineering disciplines provides the foundation for long-

term achievement of national objectives, a strong defense, continued economic growth, and an enhanced quality of life.

Support of basic research continually serves to strengthen the ability of the Nation's research scientists to conduct high-quality research and to assist in educating the next generation of scientists and engineers.

So these two examples set the extremes: One, support basic research as well as its role in training and educating future scientists and engineers—the private sector has insufficient incentives to do this on its own; two, get the Government out of the way of and out of the business of short-term commercial development. Development should be supported only when needed for such Federal roles as national security of states, or perhaps the market forces, are strongly affected by Federal regulation, such as a nuclear power.

Between these two easily-articulated extremes, policy evolved during the Reagan Administration in the areas of what is the Federal role in applied research and technology, if any, and what is the degree to which the Federal Government should encourage commercial development of inventions created in Federal Laboratories, and what cooperative R&D activities should Federal Laboratories engage in in industry.

Prior to the 1980's, the extensive Federal Laboratory system had focused mainly on research and development for traditional Federal missions, such as national security, energy, environment, health, and space. All along, however, it was acknowledged that some of this technology could spin off into the commercial sector.

For instance, the Bayh-Dole Act of 1980 permitted Government-owned/Government-operated Laboratories to grant exclusive licenses for patents that it created. This sort of technology transfer is sort of a passive program of the transit type. Industry over the years has come to realize that that's not the most effective way, and that a more cooperative, hands-on approach produces better results.

An important step towards more effective implementation of Federally-generated technology was the Federal Technology Transfer Act of 1986, supported by the Reagan Administration. This policy was that it is the continuing responsibility of the Federal Government to ensure the full use of the Nation's Federal investment in research and development.

To this end, the Federal Government shall strive, where appropriate, to transfer Federally-owned or -originated technology to state and local governments into the private sector. But in addition, technology transfer consistent with laboratory missions is the responsibility of each Laboratory scientist and engineer, not just a passive process.

President Reagan carried this further on December 22nd, 1987, when he issued his Executive Order Number 12591, Facilitating Access to Science and Technology. His Order reads in part:

In order to ensure that Federal agencies and Laboratories assist universities and the private sector in broadening our technology base by moving knowledge to the development of new products and new processes, it is hereby ordered as follows:

Each executive agency and department, to the extent permitted by law, shall encourage and facilitate collaboration among Federal Laboratories, state and local governments, universities, and the private sector, particularly small business, in order to assist in the transfer of technology.

As in the private sector, the Federal Government has realized that two-way, hands-on cooperation is by far the best way to transfer technology. Over the years, these cooperative R&D interactions have evolved and matured. As they have evolved and matured, another cost-free benefit has appeared: in many cases, a cooperative activity has resulted not only in more effective commercial implementation, but it has also strengthened the capability of the Federal Laboratories to perform their traditional core missions.

While this is just a short snapshot of the evolution of R&D policy in the Reagan Administration—consisting of three parts—one, support for basic research; two, avoid market-distorted short-term commercial development and demonstration projects; three, engage in generic technology cooperation, both to make commercialization of Federal technology more effective, and to improve the effectiveness of the Federal technology base for traditional Federal missions, it seems to me that the Reagan policies stood well over time, and can serve as useful guideposts for today. Thank you. [Audience applauds.]

[The prepared statement of Dr. McTague follows:]

Testimony of

John P. McTague
Vice President - Technical Affairs
Ford Motor Company

SCIENCE, ENVIRONMENT AND TECHNOLOGY SUMMIT: A LONG TERM NATIONAL SCIENCE STRATEGY

before the

SUBCOMMITTEE ON BASIC RESEARCH
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Held in Oak Ridge, Tennessee

June 1, 1995

Mister Chairman and Members of the Subcommittees, thank you for the opportunity to participate with you in this most timely hearing. As this nation appropriately and necessarily institutes actions to reduce and eliminate the existing federal deficit for the immediate future, it is equally important for ourselves and our children that we address the most effective means to avoid such deficits in the long run. In this day and age, few would deny that science and technology are integral to the strength and growth of the economy and to improvements in the quality of life and national security.

This observation is the easy part. The tough one is devising a set of principles and actions to maximize the leverage of science and technology for national goals. what should the federal government do? Equally important, what should it not do? What are our comparative advantages? What are we doing well, what not so well? what should we strengthen, and how, and what should we eliminate? where should government lead, where should it be a partner, and where should it get out of the way?

As you in the congress and the nation as a whole address these issues, I would like to offer some personal observations based on my experiences as a university researcher, as a user of and later a director of national laboratory research facilities, and as vice president of technical affairs in a major industrial corporation. Perhaps more relevant, however, was my time spent as deputy director and acting director of the Office of Science and Technology Policy during both terms of the Reagan Presidency.

There is considerable parallel between the evolution of the Reagan science and technology policy in the 1980's and today's debates and actions. So it might be worth looking at what was done and why.

Some choices were easy, and were made early. Some involved the federal government getting out of the way, and some called for solid support. Market distorting commercial demonstration projects, such as coal gasification and shale oil, were ruled out. In today's language, I suppose that they would be described as corporate welfare, and involved the government in attempting to pick, and subsidize, near-term commercial technologies.

Another easy one was federal support for and nurturing of basic research. The rationale for this support was summarized annually in the Special Analyses of the Budget of the United States Government, submitted to the Congress with the President's Budget. Here is a typical example, from fiscal year 1986:

"The 1986 budget continues this Administration's emphasis on the importance of support for basic research across all scientific disciplines even in a time of budget restraint. Scientific knowledge in fields such as mathematics, physics, chemistry, biology and the various engineering disciplines provides the foundation for long-term achievement of national objectives of a strong defense, continued economic growth, and an enhanced quality of life."

"Support of basic research particularly serves to strengthen the ability of the nation's research scientists to conduct high-quality research and to assist in educating the next generation of scientists and engineers. University-based researchers receive about half of the total Federal obligation for basic research and provide the critical element of education to maintain a vigorous, first-class scientific and technical pool." (FY 1986 Special Analysis K, pp K-4 & K-5).

These two policies set the extremes:

1. Support basic research as well as its role in training and educating future scientists and engineers. The private sector has insufficient incentives to do this on its own.

2. Get the federal government out of the way of, and out of the business of, short-term commercial development. Development should be supported only when needed for such federal roles as national security or space, or perhaps when market forces are strongly affected by federal regulation, e.g., nuclear power.

Between these two extremes, policy evolved during the Reagan administration in two main areas. One was the appropriate role of the federal government in applied research and technology. The second was the degree to which the federal government should encourage commercial development of inventions created in

federal laboratories, and what cooperative R&D activities should federal laboratories engage in with private industry.

The extensive federal laboratory system had focused mainly on research and development for such federal missions as national security, energy, environment, national health, and space. All along, it was realized that some of this technology could "spin off" into the commercial sector. For instance, the Bayh-Dole Act of 1980 permitted government-owned, government-operated laboratories to grant exclusive licenses to patents.

This sort of technology transfer is of the passive, sequential, "throw it over the transom" type. Industry, over the years, has come to realize that this is a very inefficient process, and that a more hands-on, cooperative approach produces better results. An important step towards more effective implementation of federally generated technology was the Federal Technology Transfer Act of 1986, whose stated policy was:

" (1) It is the continuing responsibility of the Federal Government to ensure the full use of the results of the Nation's Federal investment in research and development. To this end the Federal Government shall strive where appropriate to transfer federally ownad or originated technology to State and local governments and to the private sector.

(2) Technology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional."

President Reagan carried this further on December 22, 1987, when he issued Executive Order No. 12591, "Facilitating Access to Science and Technology." This Order reads, in part:

" . . . In order to ensure that Federal agencies and laboratories assist universities and the private sector in broadening our technology base by moving new knowledge into the development of new products and processes, it is hereby ordered as follows:

... (a) The head of each Executive department and agency, to the extent permitted by law, shall encourage and facilitate collaboration among Federal laboratories, State and local governments, universities, and the private sector, particularly small business, in order to assist in the transfer of technology to the marketplace.

(b) The head of each Executive department and agency shall, within overall funding allocations and to the extent permitted by law:

(1) delegate authority to its government-owned, government-operated Federal laboratories:

(A) to enter into cooperative research and development agreements with other Federal laboratories, State and local governments, universities, and the private sector ..."

As in the private sector, the federal government had realized that two-way, hands-on cooperation is by far the best way to transfer technology.

Over the years, as these cooperative R&D interactions have evolved and matured, another cost-free benefit has appeared. In many cases the cooperative activity has not only resulted in more effective commercial implementation, but it has also strengthened the capability of the federal laboratories to perform their traditional core missions.

This is just a short snapshot of the evolution of R&D policy in the Reagan administration:

1. Support for basic research

2. Avoid market distorting, short-term commercial development and demonstration projects.

3. Engage in generic technology cooperation both to make commercialization of federal technology more effective and to improve the effectiveness of the federal technology base for traditional federal missions.

It seems to me that these policies have stood well over time, and can serve as useful guideposts for today.

Thank you.

Chairman STEVEN SCHIFF. Thank you very much, Dr. McTague. Dr. Trivelpiece, please.

TESTIMONY OF DR. ALVIN TRIVELPIECE, DIRECTOR, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE

Dr. ALVIN TRIVELPIECE. Mr. Chairman, members of the Subcommittee, Marilyn, it is a pleasure to have the opportunity to appear before you and testify in this interesting subject today. I want to take the opportunity to thank you for doing so. I think perhaps something that many members of the audience don't appreciate is just how rare a field hearing is. You touched on that a little bit and I certainly appreciate that you do it.

I also want to, on behalf of everyone in the Third District here, thank Representative Wamp for having the tenacity and the initiative to get all this started, and you for allowing the hearing to take place. But perhaps even more for the audience's benefit here in the hearing room, it's also unusual for advice and consent of appointees to accept invitations to go out of town and appear before a field hearing. So I want to thank my colleagues here on the panel for taking the time to accept your invitation to come to this hearing. So I think it's quite an unusual opportunity and I appreciate the chance that we have to discuss this subject today.

I'd like to begin by reminding everyone that Robert Solow, Professor at MIT, got the Nobel Prize a few years ago for a rather interesting pronouncement—namely, that science and technology are the engines for an economy, much more so than in capital formation. Now, the reason that that's interesting is that, scientist or engineer, one wonders what took the economists so long to figure that out. [Parties laugh.] I think the engineers knew this all along somehow, and we wonder why people don't pay more attention to that.

So, with that in mind, then, I'm somewhat troubled by the debate that seems to be taking place on controlling the deficit in a way which might have the consequence of dismantling, or substantially altering in a negative way, some of the science and technology apparatus of the United States. And so I kind of welcome this opportunity to defend this.

But I am keenly aware of the need to try to control the deficit. But in the language of an injunction, one needs to make sure you don't do any immediate and irreparable harm to the system, you need to preserve what it is that is appropriate. So what is appropriate? Well, science and technology is easy to kill; it's hard to restore it. You take these institutions and major programs they represent out of existence, you'll find it very difficult to put them back in place.

To that extent, what does that action say to the young people of this Nation, whom I and many others have donated lots of hours of our time to serve on various committees related to it—Goals 2000, America 2000, Mathematical Science and Education Board, and things like that. That we're trying to encourage them to consider pursuing careers in math, science, and engineering for the benefit of this country, and then we take steps that cause the very facilities which many of them have counted on being there when

they receive their degrees—we're taking steps that may cause some of them to go out of existence. That kind of troubles me.

So, let me sort of pose a way by which we might discuss this. The first is, what's the difference between a winning strategy and a defensive strategy? Well, every weekend there's some major sporting event going on in this country, and on Monday morning there's a clutch of people who comment on it. And in the course of their comments they say, "Well, golly, they were ahead and they sat on their lead and they lost. If they had only continued to pursue a winning strategy." You know, any Monday morning you have hundreds of these types of comments.

But, what does that mean to the situation we're talking about here today? Well, suppose that you had the idea of a tariff as a trade barrier; is that a winning strategy or a strategy that seeks to prevent loss? Well, I think it's one that seeks to prevent loss. I prefer to engage in an activity that seeks to win.

So what are the things that seek to win? Well, in my view, supporting science and technology in the United States is a strategy that seeks to win, rather than one that seeks to prevent loss. So, if you have that in mind, then let me ask you to imagine how would you go about assessing what we've done, what we might do.

I like to use the idea of an interview—what do you do in an interview? Well, you want to know two things if you're interviewing somebody for a job. So, suppose you were interviewing the DOE Labs for a job, what would you want to know? "What have you done, and, what can you do?" Well, "what have you done,"—I could spend a lot of time talking about it—and to some extent, some of my colleagues here already have, and certainly the brief lecture by Dr. Appleton and Clifford Shull, Nobel Laureate, have talked about what we've done. And here are many things.

But let me skip past that and say about the "what can you do", how would you go about deciding what can you do? One way is to imagine the year 2030, just pick some distant time out there, and suppose that in the year 2030, you could go in and have a drop of blood taken from you, and that drop of blood could then be analyzed and quickly determine what your whole genetic map is. And from that, probably what's wrong with you. And from that, probably the medicine that you need, and have a super computer develop the medicine, if it didn't exist, and provide it to the pharmacy as you leave the hospital or doctor's office.

That's kind of far-fetched, but there are a bunch of other examples like that that I, kind of flight of fancy, included in my prepared remarks. But, could those things happen? Yeah, some of them could happen. What could you guarantee? Well, you can guarantee that if you don't do some of the work, these things won't happen.

And so, what are the tools by which you're going to cause that to occur? Well, the tools are the kind of things that my colleagues here have discussed already—universities, industry, National Laboratories, and the sound policy of investment. So maybe in the process of controlling the deficit, you should consider looking outside those cuts of science programs in the country.

Maybe there are things that are in the national scene less valuable to us if we're to have a future in which we have unlimited

clean water, unlimited energy, or other kinds of things that we might consider being very, very desirable. Can we get there? Possibly. And I think it's worth taking a shot at. And that, to me, is the winning strategy; is to set in place the actions that would cause that to occur.

So, this institution here at Oak Ridge, as well as other Laboratories and universities, have a key role to play in that, as does industry. And I would hope that the Nation would try to make a balanced investment in those things.

Since this is my home turf, I can't resist being briefly parochial. And to that extent, I would like to thank Dr. Krebs for having taken the effort to cause the President's budget to have an element in it that requests this pulse spallation source for Oak Ridge National Laboratory as the next neutron science facility. I think that's very important.

I realize that this is a difficult period in which to talk about building such a facility, the total construction cost of which may come to a billion dollars. However, it is the kind of investment that I think is valuable, it's exactly what we've been talking about here today. So I want to take this occasion publicly to thank Martha for her support, and hope that in the process of the hearings during this year that the Congress is able to allow this project to continue in such a way that it can become reality somewhere in the future. Thank you, Mr. Chairman. [Audience applauds.]

[The prepared statement of Dr. Trivelpiece follows:]

Testimony of

Alvin W. Trivelpiece
Director
OAK RIDGE NATIONAL LABORATORY

SCIENCE, ENVIRONMENT AND TECHNOLOGY SUMMIT: A LONG TERM NATIONAL SCIENCE STRATEGY

before the

SUBCOMMITTEE ON BASIC RESEARCH
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Held in Oak Ridge, Tennessee

June 1, 1995

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
Managed by
Lockheed Martin Energy Systems, Inc.
for the
U.S. Department of Energy
under Contract No. DE-AC05-84OR21400

Mister Chairman and Members of the Subcommittees, thank you for taking time from your busy schedules to hold this hearing in Oak Ridge. It gives us a wonderful opportunity to discuss our nation's science and technology needs in the 21st century. I am honored and pleased to have been invited to testify before this Subcommittee to present my views on the subject of the Federal government's role in a long term science strategy for the nation. Although the viewpoints I will provide today are largely my own, I have solicited the views of the directors of the other Department of Energy (DOE) national laboratories and several of my colleagues. I also want to congratulate Representative Wamp for his initiative, enthusiasm, and dedication that brought about this Summit on Science, Environment and Technology. It provides a great opportunity to highlight the kinds of science and technology that are important not just to this region and the facilities that are sited here, but also to the nation. In addition, it allows us to call attention to the pivotal role that science and technology play in many aspects of our everyday lives. In this period of budgetary stringencies, it is imperative to know what the benefits and consequences are when federal programs are reduced or modified. Many of the changes being considered will cause immediate and irreparable harm to science and technology programs that are important to our nation. Such changes should not be made blindly. I hope that the activities associated with this Summit help shed light on the pros and cons of some of the proposed changes in particular elements of the government's science and technology programs.

It has been said many times, in many ways, that World War II forever changed the way that we did many things. That is certainly true of the research and development enterprise in the United States and around the world. As a result of the war time efforts, the model of a single professor working with a few graduate students in isolation at a university was replaced by an approach that involved teams of scientists and engineers working in a collaborative manner on a common problem or set of problems. The development of nuclear weapons and radar are two of the most dramatic examples growing out of the WW II experience. One of the principal entities that was caused by, and initiated much of, the change in the way that research was conducted was the Atomic Energy Commission (AEC), which was created in 1947. It in turn became the Energy Research and Development Administration (ERDA) in 1976, followed shortly thereafter by the establishment of the DOE in 1977. These entities have fostered and supported a superb system of national laboratories, a collection of imaginative educational programs, and programs of outstanding research at our universities.

From their beginnings, the DOE national laboratories have been leaders in using a multidisciplinary approach to solve large, complex scientific and technical problems. These laboratories have created and developed unique facilities and instrumentation for attacking

Suppose that the national laboratories were applying for a job, and that you were the interviewer for your company or institution. What would you want to know about us? Usually most interviews boil down to just two questions. What have you done? What can you do? Using the Hearing Charter as a guide, I would like to provide a partial answer to these questions as they pertain to the DOE national labs.

The first of the interviewer's questions is, "What have you done?"

I could list the individuals who have received Nobel prizes for work done that involved some aspect of a project at one of the labs. You have just heard from one of them, Professor Clifford Shull. It is easy to see that what he did many years ago has had a profound effect on many areas of today's science and technology. No one would question the value of the investment that made it possible for him and his colleagues to do their seminal work. I could list many other technical accomplishments of a similar nature, but these have been written about extensively and there isn't time to discuss them here. Rather, I want to go over a few items that help set the stage for suggesting how we might be more useful as a set of laboratories to the nation.

Originally established to support our country's research and development efforts during the Manhattan Project, the DOE national laboratories have evolved into broadened missions in response to national needs. The goal of the Manhattan Project was to harness nuclear energy and use it to create nuclear weapons. Along with this goal came the need to understand the biological effects of ionizing radiation and the possible benefits to humans from nuclear materials. From this beginning, the biological, environmental, and health programs expanded to cover all forms of energy production. A significant outgrowth of this program was the development of medical radioisotopes. This development set off a collection of activities that led to the creation of the field of nuclear medicine, the development of flow cytometry, and research on the efforts to map the human genome. It is estimated that each year more than 100 million Americans receive diagnosis or therapy using some aspect of nuclear medicine. The value of the role of isotopes to the world is well stated in a remark made by an earlier director of the Oak Ridge National Laboratory (ORNL), Dr. Alvin Weinberg. He said, "If at some time a heavenly angel should ask what the laboratory in the hills of East Tennessee did to enlarge man's life and make it better, I daresay the production of radioisotopes for scientific research and medical treatment will surely rate as a candidate for the very first place." I believe that the value to the world in terms of the knowledge gained from the use of stable and radioactive isotopes has

The things that they learn make them better trained, and I believe that some of them gain specific knowledge that they may use later in their careers. This is every bit as much technology transfer as a patent or a publication. Over 24,000 precollege students visit ORNL annually, and other DOE labs have similar experience with their precollege visitors. The same benefit to the general circumstance of tech transfer is obtained by the Department's many programs for undergraduate and graduate students, some of which date back almost to the beginnings of the DOE national laboratories. DOE is not in the education business and does not compete with academic institutions in any way. It would be shameful not to use the resources of the Department to give some of our students the opportunity to participate in programs that give them a better grasp of what science and technology are all about. I want to take this opportunity to congratulate Secretaries of Energy Herrington, Watkins, and O'Leary, for their strong encouragement of education programs at the DOE national laboratories. Without their support it would be much more difficult to have our facilities used give some of our young people some exposure to working scientists and engineers, and as a result, perhaps inspire some of them to pursue careers in these fields of study.

Now let us turn to the other aspect of an interview.

What can we do?

To answer this question, it is necessary to first speculate on what might need to be done. I ask you to join me in a flight of fancy and try to imagine what the world might be like in the year 2030. What kind of a world might we like to have our children inherit? What kind of a world could it be if we do the right things?

For instance:
Imagine that in 2030 genetic diseases are curable. Through knowledge of the genetic code, a single drop of blood is used to diagnose an illness and design an individual's unique treatment. A supercomputer tailors the medicines to the specific needs of the patient and causes them to be produced, if they are not already off-the-shelf items.
Imagine that in 2030 energy supplies are increasingly non-depletable and secure.

Imagine that in 2030 poverty, terrorism, and threats of war are small, that the economic gap between developed and developing countries is closing with population stabilization due to sustainable economic development.

almost certainly be more expensive and less effective in the long run. One thing seems clear, without better science and technology we won't achieve desirable goals for 2030. We will not succeed without a systematic effort to know more about the problems that we face, although at times I suspect that some people believe that we shouldn't advance the state of our knowledge in science and technology.

Now I would like to address the questions posed in the Hearing Charter.

Nonetheless, the labs should not be converted into job shops that have as a principal task the requirement of servicing industry. In this regard, the Galvin Task Force is correct in making the recommendation that economic competitiveness should not be a primary mission of the DOE national laboratories. Collaborations with industry and universities should be viewed as resulting from the labs' missions, but they should not be a primary lab mission. Through their partnerships with industry, the Department's national laboratories help maximize the value of the public investment by increasing the prospects of getting taxpayer-financed innovations to the marketplace. Technology transfer takes many forms. Technology developed through CRADAs is but one of them. The publication of research results in scientific journals is another form - one that I believe is less appreciated. DOE's research and development efforts that are published should be available to anyone who chooses to read the scientific literature and take advantage of the research. There is concern that other nations gain by our openness. This is undoubtedly true, but our collective failure to capitalize on the results that we produce should not be a prime argument for turning off the research enterprise that produces innovation or new knowledge.

Many of the technology successes that have grown out of the national laboratories have their origins in their science programs. I would like to give two examples that illustrate a circumstance where the successful outcome of energy efficiency projects was based on some aspect of fundamental science.

Alternative-fuel vehicles offer both potentially lowered emissions and freedom from dependence on petroleum for transportation. These vehicles can be powered by alcohol fuels that are converted from biomass - plant matter such as stems or branches. ORNL manages DOE's Biofuels Feedstock Development Program, a national program for the development and demonstration of commercially viable biomass supply systems. This program is done in close coordination with the National Renewable Energy Laboratory, which is developing new processes for converting plant biomes to fuels. The research program involves universities, the U.S. Department of Agriculture, and industry collaborators. Contributing to the foundation for this effort is the science supported by the DOE Office of Health and Environmental Research on global climate change. By studying the basic response of plants to the stresses of the environment, it is possible to determine the effects of global climate change and why plants exhibit pest, disease, or drought tolerance. These results can then be used by the Biofuels Program to develop increased yields. This activity is a result of natural collaboration by which the various parties felt that they could make better progress by so doing, and not the result of a high-level policy decision that mandated collaboration between these specific entities.

One indication of new ideas and innovation is the recognition received for technical usefulness, importance, and uniqueness. Every year, *R & D Magazine* honors the top 100 innovations in applied science by presenting its R&D 100 Awards. Recognized widely as a symbol of excellence, the awards are pursued by universities, national research facilities, and private industries worldwide. Extremely diverse, these projects are cited for significant advancements in such fields as medicine, environmental science, advanced materials, and analytical instrumentation. In 1994, the DOE received 28 R&D 100 Awards for an all-time total of 392. ORNL ranks fourth among institutions in the all-time competition, with 74 awards won since 1967.

One of the criteria for judging basic and applied research activities is excellence, the same standard that is used at evaluating research and teaching at universities and other institutions. National laboratories have much in common with universities because graduate education is an important element at both institutions. Some national laboratories, like Lawrence Berkeley Laboratory (LBL), are integrally connected with institutions like the University of California. At other laboratories, such as ORNL, the cooperation with institutions such as The University of Tennessee is not as great but is still significant. The National Science Foundation (NSF) issues an annual report detailing the financial support provided to universities' external research and development efforts. The latest report indicates DOE support to universities totals about $700 million. Unfortunately, this number excludes the support provided by the national laboratories to the university community. This support, when combined with the direct DOE grants, totals well over $1 billion. But even this total does not take into account the work done at institutions such as Fermi National Accelerator Laboratory, which exists primarily to serve research that is initiated at universities and other labs. At The University of Tennessee, over 20 percent of the $72 million in external research and development is supplied by ORNL, with significant additional funds provided by other DOE facilities in Oak Ridge. These numbers only provide the financial picture and do not measure the intellectual contribution of the national laboratories. Another measure is the contribution made to graduate education through involvement of graduate students at the national labs. Over 500 graduate students now actively participate in research projects at the LBL alone. All of these examples point to close ties between universities and the national labs. Management of the national laboratories is, in essence, a trustee responsibility that is similar to the management responsibility of the trustees of major universities.

An impressive statistic is the 15,000 scientists and engineers who visit DOE laboratories for an extended period of time. ORNL had over 4000 guest scientists and engineers (defined as those

2. *With the Administration and the Congress projecting decreasing Federal budget support for research and development over the next five to seven years, how must the relationships between the Federal laboratories, the research universities, and industry evolve to assure adequate science and technology investment for the nation's future.*

I have had the good fortune to visit research institutions in many countries, and I have had the opportunity to meet with delegations visiting the United States from other countries. It is my impression that most of these countries envy our system of national laboratories. In many cases they have set up institutions that are similar to ours. Therefore, I find it perplexing to learn that there are recommendations to establish a version of the Defense Base Closing Commission to decide which of our national laboratories should be closed. Research laboratories are not the same as military bases in the sense that even though base closing may be painful and economically disruptive in a particular location, the process is easier to reverse than the closing of a major national laboratory. If the need arises, the bases can be reopened. The military function they performed can be completely restored, even though it may be at another site. With research labs it is a little different. The processes that bring together a group of productive scientists and engineers into a multiprogram activity are not so well understood. It may take years to get a productive group going and only a few minutes to kill it. Like many of my colleagues, I am distressed that several large industrial laboratories have significantly weakened there long-term commitments to R & D in the course of downsizing and realignment. Bell Labs and IBM are the most recent to come to mind It would be difficult to recreate a research institution like Bell Labs here in the United States. It is my understanding that as a condition of doing business in both Singapore and China, AT&T is setting up research institutions like Bell Labs in those countries. This pattern worries me. I hope that it worries you also.

If the present round of budget considerations is going to reduce the support for research, then I believe that the Administration and the Congress should agree on what programs or projects are going to be continued and which are going to be eliminated, rather than asking which institutions should be affected. If a given program reduction results in a reduction at a national laboratory or university, so be it. The institution(s) best able to perform the program should either be assigned to do the work or allowed to propose to compete for it. Making a decision to close a facility that is best qualified to do a particular project, and then deciding to expand that particular project makes no sense at all.

As an example of how program cuts affect a laboratory, consider the decision to stop work on one version of a new production reactor. This programmatic decision resulted in a $14 million

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The DOE national laboratories are an essential component of this system. Their ability to conduct large-scale, long-term, integrated research projects has produced a remarkable set of contributions, ranging from fundamental scientific discoveries to commercial products, that have improved national security, economic productivity, human health, and environmental conditions. The success of the national laboratories in applying science and technology to national challenges derives in part from a special organizational structure that supports long-term, high-risk, problem-focused research and development. Successful projects have been characterized by interdisciplinary integration of science and engineering, focused project management, defined cost and time schedules, and relevant delivery of solutions to problems. The report of the Task Force on Alternative Futures for the Department of Energy National Laboratories (the Galvin Task Force) notes, "One of the great strengths of the multiprogram laboratories derives from the diversity of technical expertise that can be brought to bear from within these laboratories on specific scientific and technical challenges."

In recent years, DOE and other agencies have increasingly managed research using the academic model, supporting small projects that are reviewed individually. The Galvin Task Force called attention to the "institutional fragmentation" that has resulted from the funding of hundreds of small projects, led by individual investigators, that do not take advantage of the unique research and development capabilities of the national laboratories. To assure adequate science and technology investments for the future, DOE should fund projects less on a retail basis and more on a wholesale basis that leaves some of the programmatic decision process to the directors of the labs. Several recommendations in the Galvin commission's report call for greater integration of research at the laboratories as a means of counteracting this fragmentation and improving the laboratories' ability to contribute to solving important national problems. As the nation moves toward the development of a long-term science strategy, the definition of the role to be played by the national laboratories assumes even greater urgency. New research and development management approaches are needed to sustain the technical integrity and excellence of the scientific programs at the national laboratories and to prepare the laboratories to respond to the challenges of the future.

It is tempting to summarize this section by saying that only the most relevant or most excellent programs should be funded, that the best performer should be the one to do the work, and further that the best way to make this determination is via the process of peer review. Although I have personally benefited from the peer review process in the conduct of my own research in the past, I am not a believer in the notion that it should be the only path to assignment of funds for basic or applied research. Peer review is a means of maintaining the *status quo*.

3. Would integration of all Federal science and technology agencies into a single, cabinet-level department contribute to more efficient support for research and development?

I have never been a fan of the idea of a single cabinet agency for science and engineering research support. This opinion is based in part on my experience during the twenty years that I was a professor of engineering and physics, and in part on my service as a federal employee. I know that the idea has a certain current popular appeal, but I believe that it is a bad idea for several reasons. The appeal for a single agency is the argument of efficiency; namely, the belief that such an agency would eliminate duplicate programs that the present system is believed to cause. I don't believe that the assumption is correct. The present system does not produce duplication of research, unless some federal employee is intentionally spending the federal funds entrusted to him or her in a manner that causes that to happen, which would be unwise if not illegal. Even if duplication of funding for similar programs were to occur, the scientists or engineers involved in the project would eventually have to publish the work based on the funding. It is unlikely that promotion to a better job code or tenure in a university would occur, or for that matter that funding would be continued, if it could be shown that the work was identical to someone else's. This might even raise the consideration of scientific fraud or plagiarism if such duplication were to occur. Since such events are exceedingly rare, it would seem that reduction of nonexistent duplication should not be the basis for the establishment of a science agency. The present system may be a little inefficient, but it is certainly effective. The current system provides a variety of approaches to solving the Nation's research and development challenges. While there may be an overlap in the goals of some of the research, the matter of duplication of research results is well taken care of by the time-honored tradition of the goal of scientists to be first to publish results.

Agencies do collaborate now to increase efficiency in research and development support. Collaboration exists between the DOE and the NSF is in the area of nuclear science. The Nuclear Science Advisory Committee is responsible for developing a long-range plan (roughly every 5 years), and advises both the DOE and the NSF. However, this does not imply joint funding of major projects. What it does imply is that the community coordinates projects across both agencies to maximize the new science and eliminate the possibility of duplication. This is planning in response to the new directions identified by the whole nuclear physics community. Hopefully, this means that by the time these proposals go to Congress for funding, the nuclear physics community has completed all of its internal discussion and battles over priorities, and now speaks with one voice. Discussions are under way to identify the highest priority for new construction once the Relativistic Heavy-Ion Collider at Brookhaven is complete. This could

4. What is the appropriate role of the National Science Foundation and the research universities in research and development in the energy and environmental sciences? How is this best integrated with DOE-supported research?

Considering all of the sources for the support of academic science and engineering, both the NSF and the DOE provide support at about the same level. The NSF focuses its resources on support for fundamental research in our nation's colleges and universities; the exception is in the biomedical sciences where the National Institutes of Health is the primary sponsor. Most of this support is designated for individual principal investigators or other small teams. Academic researchers rely on the NSF because it also supports research facilities, like accelerators and observatories, and other academic facilities modernization programs.

An important consideration is that the concept of multiple funding sources is not bad. This is just the opposite approach of having a single science agency. Agencies with specific missions may hesitate to fund an outstanding idea because its relevance to the agency's mission cannot be clearly demonstrated. The NSF can fund quality projects in areas for which relevance is unknown; that is part of the mission of the NSF.

The DOE is sometimes criticized because it is believed that too much of its research and development are in areas that are not obviously related to energy, such as health and environmental sciences. Some of these DOE programs have their origin in the Atomic Energy Act of 1946, which provided for research and development activities directed to "the preservation and enhancement of a viable environment by developing more efficient methods to meet the Nation's energy needs." The environment is invariably affected by energy production and supply: producing energy involves substances that come out of the ground and eventually go back into the ground; while these energy resources are out of the ground, they can affect people, plants, air, and water. Also mandated in the Atomic Energy Act of 1946 was the need to understand the consequences of radioactive materials and "the protection of health and the promotion of safety during research and production activities." From work to develop an understanding of the effects of large doses of radiation and chemical substances, DOE researchers have moved to improving their understanding of the long-term, low-dose effects as well. The disadvantages of using laboratory animals for such studies led to present efforts to understand these effects at a molecular level. DOE's pioneering involvement in these programs flowed from the need to understand the effects of exposure to radiation and chemicals on plants, humans, animals, and the environment. It was this need to understand these effects that led DOE

sciences. While these examples represent the application of recent developments in the social, behavioral, and economic sciences, they could not have been accomplished without the methodologies having been first developed in a basic research context.

For a number of years ORNL has been examining the best ways to dispose of chemical weapons currently stored at facilities in different parts of the United States. Our work includes the examination of emergency evacuation measures in addition to the best technological measures for destruction of the weapons. Our work on emergency evacuation from these sites directly applies recent basic research in behavioral and social science to reduce the loss of life and property. For example, basic research on cognitive information processing and social relations coupled with field studies of human response to emergency warnings has led to new warning technology and warning messages which are much more effective in getting people to protect themselves in an emergency. The implications of our work extend beyond chemical weapons, as a recent ORNL report on warning systems is now required reading for all National Weather Service forecasters. Likewise, the techniques developed by our social scientists have led to more effective training and public education programs that are, unfortunately, making the headlines in our daily newspapers. Immediately after the Japanese subway chemical attack, the New York Transit Authority used a training course and video entitled "Act Fast," which was produced by ORNL for the Federal Emergency Management Agency, to train emergency personnel on how to respond to a similar chemical agent attack if it occurred in New York City.

The social and economic sciences also play a major role in evaluating the effectiveness of government programs. For example, during 1994 ORNL completed a three-year evaluation of the nation's single largest conservation program - DOE's low-income Weatherization Assistance Program. The goals of the Program are to decrease national energy consumption and to reduce the impact of high fuel costs on low-income households, particularly those of the elderly and the handicapped. A comparison of costs and benefits based on a range of assumptions concluded that the Program is a cost-effective government investment. Also, as a result of the findings of this evaluation, DOE has initiated major changes in the program to reflect the practices which were identified to be the most cost effective.

A final example that illustrates my point is a recently completed study that developed a method for estimating the externalities associated with the generation of electric power from six different fuel cycles; coal, biomass, nuclear, hydropower, oil and natural gas. Externalities are the costs, such as health and environmental costs, that the technologies impose on third parties. In other words, the impacts that producers and consumers do not take into account during the normal

5. What are the DOE and national laboratories doing to establish clear mission statements for the labs which can be utilized for future budget decisions and long-term strategic planning?

The question implies that the mission statements of the DOE's laboratories are not clear. I believe that they are clear and simple. The problem is that taken at face value they do not differentiate one lab from another in a simple and concise manner. The same could be said of universities. Their mission statements would all sound similar and would not distinguish one institution from another. And yet, they vary greatly in the emphasis which they give to different functions within them. Some emphasize science and others liberal arts or business, even though each would have some activities in all of these areas, even if it was not the most excellent. Suppose that universities were asked to focus their efforts so that they could be made more efficient by terminating those activities that are duplicated at some other university. Maybe one university has an English department, while another has a physics department, and still another has neither, but does have a football team. This would be a silly approach to operating the universities in our country.

What about the DOE national laboratories? Should one of them do physics and another one do chemistry? No, that doesn't make sense either. Part of the problem with mission statements is that the effort to reduce the diverse collection of activities at any of the labs to one sentence yields nearly identical sentences. I believe the better question to ask is, what is being done by DOE and its laboratories to ensure that the highest quality work is being funded consistent with the requirements of the DOE Act, and the other pieces of enabling legislation that precede it? The various reviews that have recently been conducted as well as those now under way should help, but this is a never ending process. The various advisory committees that help the DOE in assessing the quality of its programs should be continued. The visiting committees of distinguished scientists and industry leaders that each laboratory has to help insure the excellence of its programs should be continued. Periodic comparisons of the quality and excellence of the work done at all national labs with that being done at academic institutions and industry would be advisable. There is no simple answer to the question posed, because it is based on a faulty premise.

new ideas is never easy, it is more difficult for those researchers not in the mainstream to receive funding or to receive timely recognition for new ideas that provide refreshment and renewal. Despite the imperfections of this process, it has served us well and forms the basis of most program funding choices. For the traditional "mission" areas, this is still the best measure of performance. However, as the laboratories have increased their emphasis on economic competitiveness and education, other sectors of the nation have become important as customers and, therefore, as evaluators. Reviews by these new customers should be used to assess the performance of the laboratories in their new roles. Both customer surveys and proposal reviews are obvious mechanisms. Depending on the role, the appropriate customer may be private industry, academia, other Federal agencies, or state or local governments.

representatives on the advisory boards, something that has been done for decades within the laboratory system, and their participation in developing the technology roadmaps helps assure the relevance of the research and development performed by the centers.

The first virtual technology center for bioprocessing was formed in 1993, a second is being formed in advanced robotics technology, and over a dozen other centers are in the embryonic stage of formation. Integrating competencies across the laboratories through a virtual center would be expected to accelerate the advancement of technology, assure customer accessibility to the best resources, aid retention of core competencies, reduce cost, and help the laboratory system be a technology provider of choice for specific technologies in the 21st century. All of these benefits are particularly useful in a time of constrained federal support.

In summary, a policy that supports the formation of virtual technology centers, in particular with support for a built in user center(s), is moving in the right direction.

Work for other federal agencies and for the public and private sector directly supports DOE's goals. This work also stimulates new research and development initiatives, is a key part of the technology transfer function, and helps to sustain and build the laboratories' core competencies. Although Work for Others (WFO) funding comes primarily from other Federal agencies, work with the private sector is increasing. In this manner, WFO provides benefits to the nation. WFO has served as the primary mechanism for providing DOE's highly specialized and/or unique technical capabilities to non-DOE entities. As DOE's budgets have declined, it has also served as a means of retaining, and advancing, scientific and technical excellence within DOE. To the benefit of DOE, the capabilities and advancements made with WFO funding have often found ready application within DOE itself. The report of the Task Force on Alternative Futures for the National Laboratories (the Galvin Task Force) noted, "There is abundant evidence for the beneficial role the national laboratories could play in helping resolve national problems in the numerous advances that they have already made."

Clearly, both DOE and its laboratories benefit from WFO. However, several impediments are imposed by the requirements governing the WFO program. Since FY 1989, DOE has seen a continual decrease in WFO funding. In FY 1995, the amount of new WFO funds coming into DOE has dropped significantly. Among likely reasons for this decrease, one is the decline in research dollars available from the Department of Defense (DOD) and other federal agencies. Another likely reason that is not so obvious involves sections of two acts passed by Congress: (1) the National Defense Authorization Act of 1994 (November 1993), Sect. 844, "Department

The report of the Galvin Task Force states that DOE "must take positive steps to encourage" the national laboratories to contribute to the solution of national problems and recommends that "The national laboratories... should become in fact, as well as in name, national laboratories." The national laboratories need to be national laboratories in more than name only. I believe that DOE is committed to working aggressively with other agencies to match laboratory capabilities with national research and development needs. At ORNL, we are hopeful that one result will be increased opportunities for the national laboratories to participate in some important research areas in solicitations by other federal agencies (notably the Environmental Protection Agency, the NSF, and the U.S. Department of Agriculture). ORNL also looks forward to the comprehensive report on work for other agencies that is being prepared for presentation to the Laboratory Operating Board.

Federal law, regulations, and DOE orders all require that a valid appropriation or budgetary resource exist before obligations may be made or costs incurred for work performed at a national laboratory. In compliance with guidance from DOE (letter of June 29, 1994, from Thomas T. Tamura, DOE Principal Deputy Assistant Secretary, Human Resources and Administration, to Alvin W. Trivelpiece, Director, ORNL), a cash advance is now required for proprietary work in user facilities sufficient to maintain a 90-day prepayment. This guidance is not consistent with industry's customary practice of not paying in advance for work to be performed; it is offensive to potential customers; it is overly complicated to manage; and it creates a barrier to encouraging industrial participation in DOE work.

SUMMARY

The DOE national laboratories have a valuable roles to play in the nation's long-term science and technology enterprise, but they must be managed so as to take effective advantage of their unique attributes. I hope that the Congress and the Administration will work together to find ways to continue the work at the laboratories and not succumb to pressures to do away with them.

Chairman STEVEN SCHIFF. I thank you very much, Dr. Trivelpiece. By the way, thank you for your personal courtesy and hospitality in showing me around a portion of Oak Ridge National Laboratory this morning. I very much appreciated that. Dr. Hamilton, please.

TESTIMONY OF DR. JOSEPH HAMILTON, CHAIRMAN, DEPARTMENT OF PHYSICS AND ASTRONOMY, VANDERBILT UNIVERSITY, NASHVILLE, TN

Dr. JOSEPH HAMILTON. Thank you very much. I deeply appreciate being asked to speak. You have heard from the lofty heights of the Laboratory Directors, and the heads of agencies and industry. What you're going to hear now are remarks from the working-class folk. [Parties laugh.] That's mainly the university scientists and their graduate students who get out and use those DOE National Laboratories, and for whom those DOE National Laboratories are essential for their research activities.

And ultimately, as a result of that, because we're the people who train the future scientists and engineers who are so essential for the future economic strength and growth of our country, the National Laboratory partnerships which have emerged between universities and National Laboratories, I want to emphasize as being absolutely critical for our future.

And in particular, I would like to point out that in the State of Tennessee, we have developed some very unique partnerships which I think need to be moved to other states as well as other National Laboratories. And I refer to the unique partnership between the State of Tennessee, the universities in our state, and Oak Ridge National Laboratory.

Beginning as early as 1970, the State of Tennessee, Vanderbilt, and the University of Tennessee, Knoxville, and Oak Ridge National Laboratory initiated the first of several very unique partnerships, which were farsighted, that have had really major impacts on research and on graduate education in the State of Tennessee, the Southeastern region, across the Nation, and internationally.

These partnerships, I would stress, provide models for how to effectively marshal our more limited resources, financial resources. And, more importantly, to share scientific talents and ingenuity to create world-class facilities. In which, the universities participate with the National Laboratory people in the development of those facilities, not just financially, but also scientifically.

And it's the sharing of those cooperative efforts that provide the real strength, both for our universities and for our National Laboratories. It is important to our Nation that these be full partnerships and not just National Laboratories opening their doors to the universities, because it's a way to collectively maximize the strengths that we have on both of those institutions. I would also stress that such cooperative efforts, indeed, between our universities and the Department of Energy's National Laboratories are critical for the continued health and strength of our Nation's basic research and our training of scientists.

I will use as an example—because I happen to be a nuclear physicist and I use the facilities at Oak Ridge National Laboratory—I will use an example nuclear science. But I remind you that there

are all sorts of facilities available at our National Laboratories, some of which have already been mentioned, and I couldn't help but think of the Materials Characterization Laboratory and the High Temperature Laboratory at Oak Ridge.

Just this week we were seeking to hire a named chair in Physics at Vanderbilt, someone in Condensed Matter Physics whose expertise is in silicone materials—and I don't need to tell you how important silicone materials are—but his comment was, one of the strengths of the Vanderbilt offer is the presence in Oak Ridge National Laboratory the Materials Characterization laboratory. And one of the reasons why he may come to Vanderbilt is just the fact that he can make use of those unique facilities. And so we're delighted to see those partnerships expand in other areas.

The first partnership with ORNL was something called the UNISOR Consortium, which stands for University Isotope Separator at Oak Ridge. And, indeed, Vanderbilt and the University of Tennessee approached the State and got the State behind us. And we agreed to buy an isotope separator, which was the first isotope separator placed online in the United States for studying nuclei particle stability.

At that time in 1971, it was also a time of very tight budgets. And if the universities hadn't taken this step, many of the universities in the southeastern region would simply have stopped having on campus nuclear programs, because accelerators were expensive, and fewer and fewer would be built. And therefore, it was important for them to cooperate to develop programs for their research.

Out of that, there are now currently thirteen universities corresponding to the states of Tennessee, Georgia, Kentucky, Louisiana, Mississippi and South Carolina in our region, and Texas, Oregon, Maryland, and Oxford University in England, who are parts of the UNISOR Consortium. I would also stress that the UNISOR Consortium played an important role, but you have to remember that in 1971, DOE Laboratories were not essentially used by university scientists, they were laboratories built for the scientists themselves. And UNISOR played a very important role in helping to open up Oak Ridge National Laboratory for use by university scientists.

In the late 1970's, a second partnership began when the Holifield Heavy Ion Research Facility began to be developed at Oak Ridge National Laboratory. And that's still the world's largest twenty-five-million-volt heavy ion accelerator. Vanderbilt and the University of Tennessee, and Oak Ridge National Laboratory, along with the State of Tennessee, entered into a new partnership called the Joint Institute for Heavy Ion Research.

That institute is a unique institution in the nuclear facilities in our country. It was conceived to help make the new laboratory—which was a change in direction for DOE—to make it a used laboratory by scientists from around the country and not just a national facility. As a result of the Joint Institute, we built a million-dollar building, about six hundred thousand of which came out of state and university funds.

On site at the laboratory, we then approached the State of Tennessee, and through the graces of Governor Alexander, he finally initiated a new Centers of Excellence Program, which provided

money for a visitor's program for our Joint Institute for Heavy Ion Research. Out of that Institute, we helped to make the Holifield Laboratory the most used laboratory in the Nation, in terms of the DOE's nuclear laboratories.

In the last ten years of its full-time operation before it was shut down to restructure it, in terms of new radioactive ion beam facilities that I'll mention, six hundred and forty scientists from some hundred and forty institutions, including two hundred graduate students and thirty-eight undergraduates, worked at the Holifield Laboratory.

In 1990 alone, the last year of its full-time operation, there were fifty-nine graduate students who used the Holifield facility for their research work for part or all of their Ph.D. thesis. That number was five to ten times the number at any other DOE Laboratory, and the Joint Institute played a major role in helping make that possible.

Other efforts of the Joint Institute have been the fact that it's been a host for a number of conferences, that over two thousand scientists have attended some thirty-five conferences held at the Joint Institute buildings.

Partnerships between the universities and the State and the National Laboratory have continued as universities have taken a role in helping to develop new facilities for the Laboratories. In particular, I'll make mention of the new Recoil Mass separator, which was initiated with the universities, identified—well, we raised one-point-five million dollars of the cost of that two-point-two-million-dollar device before DOE said cease and desist, we'll provide the rest of the money for you. And which they did, and then provided a building that cost another million and a half to do.

So we have a new four-million-dollar, world-class facility that's about to become operational this summer at Oak Ridge National Laboratory. Through a cooperation between the universities, the State of Tennessee put up a half-a-million dollars for it, and Oak Ridge National Laboratory and the Department of Energy.

Other outgrowths of the Joint Institute have been, as earlier was mentioned, the high-performance computing initiative which was funded at Oak Ridge. But, I remind you, that part of that funding came about because of the fact that the universities are a part of that initiative. And that new high-performance computing facility enables university scientists to make computations on problems and to attack problems which, without those new facilities, they simply would be too massive to be carried out.

Another part of Governor Alexander's Centers of Excellence Program that's unique in the State of Tennessee is the Science Alliance Program between the University of Tennessee, Knoxville, and Oak Ridge, in which they share joint appointments of distinguished scientists. And they, indeed, have brought a number of world-class scientists, as described in the Appendix C of my testimony, to the area as joint appointments. And this has also helped to transform the quality of research. It's an outstanding example of a specific partnership between a university and a National Laboratory.

Finally, I like to do things in the concrete and let people see something. If you'll give me about four minutes, I'd like just to show you a few examples of pictures from the Laboratory to let you

see what I mean, in concrete, about university uses of Oak Ridge National Laboratories.

[Whereupon, Dr. Hamilton utilizes overhead projections.]

I begin with one from the UNISOR Consortium. When we finally put together a helium refrigerator, which was on the end of the isotope separator—and you see in this picture a group of scientists who were celebrating that we'd had our first onsite successful run—they include people from the University of Kentucky, University of Tennessee, Louisiana State University, Oregon State University, Mississippi College, and Vanderbilt University.

The Joint Institute is one of the real strengths, because it provides an onsite, university-type atmosphere for users of the Holified Heavy Ion Research Facility. We have a conference center, we have spaces for people to live. It's this Center which has helped make Oak Ridge National Laboratory so much used by scientists from around the country.

One of my colleagues at Oak Ridge made this transparency for me that shows the number of guests in '93, '94. You will note that in that particular time, there are a large number of Europeans who are listed over here, and that's because of the fact that during this period Oak Ridge is in the process of reconstructuring (sic) its accelerators to become the first radioactive ion beam facility in the Nation. And many of the experts in that area are in Europe, and we have been able to use Joint Institute funds to bring those people. And that's critical to bring them from Europe, because foreign travel funds aren't so easily available always from DOE. So the partnerships have paid off in helping to develop this new laboratory.

I show an example of what that new laboratory is to look like. At the upper part is the cyclotron, which will provide the beam to make the radioactive isotopes, which will produce a target at this point—I should've brought my pen over—but in any case, they then are separated through a mass separator, sent to the second accelerator—the twenty-five million volt tandem—and then the beams of radioactive isotopes are put forward.

I notice that of the three major facilities which are in this diagram—namely, the isotope separator, the UNISOR facility, and the spin spectrometer—all three of those facilities, universities played a major part of the development of those facilities, both financial and the actual design and construction of those devices.

And that new recoil mass separator—which I'm particularly proud of and is something which I worked on for ten years—is almost completed. This is a view of that recoil mass separator. That, in conjunction with the new Radioactive Ion Beam facility, will make Oak Ridge National Laboratory a premier facility in the world. And universities will rightfully share in the acclaim, and in the research.

Finally, I would simply like to make one other final thing. You can say that it's nice to look at things in the concrete; I've spent a long time at Vanderbilt University, and over my career, I want you just to see what impacts Oak Ridge National Laboratory has made in terms of one specific concrete example in nuclear science. And that's a summary of what my group has done at Vanderbilt in the last thirty-five years.

We have trained twenty-four Master's degree students, fifty-three Ph.D's, and seventy postdoctoral research Associates, almost all of whom use Oak Ridge National Laboratory facilities for part or all of their work. These people occupy positions in colleges and universities, medical schools, hospitals, industries, government agencies, and National Laboratories.

Including, for example, one of our undergraduate students whom I think I helped influence in Physics, is now one of the Directors at one of the large laboratories for Sandia, in Albuquerque, Pace Van Devender. Others of the students who have come out of that group, one of them happens to be working at Oak Ridge National Laboratory, who won an award for his environmental cleanup of the mercury which accidently got dumped along with some field dirt on a school yard in Oak Ridge, Tennessee.

Of others in that group who have won awards, there are laboratories like Idaho National Engineering Laboratory, for the development of new techniques for inspection of missiles. Back before the Cold War when we were trying to do SALT Treaties, they developed a new technique for determining whether missiles were, in fact, still active or not, in a non-destructive way, so they could tell whether somebody was cheating on them in missile disarmament or not.

These people occupy all sorts of things. And in addition to that, we have succeeded in doing an enormous quantity of research that we think has contributed to our knowledge of physics over the years.

What I'm trying to stress is that our National Laboratories, both as seen from a concrete example and as seen from the standpoint of all these people who are using those National Laboratories—from universities and graduate students—they are essential to the health of our universities, they are essential to the continued training of nuclear scientists, condensed-matter scientists—a whole range, from physics, chemistry, biology, engineering, and computer science.

And I wish to stress, the partnerships which have developed between universities and National Laboratories in a time of austere funds—these can pay the biggest dividends that we have in the development of strengths for our future scientific enterprise. Thank you. [Audience applauds.]

[The prepared statement of Dr. Hamilton follows:]

TESTIMONY to COMMITTEE on SCIENCE

U.S. HOUSE OF REPRESENTATIVES

UNIQUE STATE - UNIVERSITY - NATIONAL LABORATORY PARTNERSHIPS

JUNE 1, 1995, OAK RIDGE, TN

Joseph H. Hamilton
Landon C. Garland Distinguished Professor of Physics, Vanderbilt University
Director Joint Institute for Heavy Ion Research, Oak Ridge

UNIQUE STATE - UNIVERSITY - NATIONAL LABORATORY PARTNERSHIPS

The State of Tennessee, Vanderbilt University, the University of Tennessee Knoxville, and Oak Ridge National Laboratory in 1970 initiated the first of several unique partnerships that have had major impacts on research and graduate education in the State of Tennessee, the Southeast region, across the U.S. and internationally. These partnerships provide models of how to effectively marshall limited financial resources and share scientific talents and ingenuity to create world-class research facilities for use by university faculty and graduate students and national laboratory scientists. These partnerships have involved not just the sharing of financial resources but equally as important the sharing of scientific insights and efforts by university and laboratory scientists to build major new research facilities at a national laboratory. It is important to our nation that these be full partnerships and not just national laboratories opening their doors to universities. In this way we will maximize collectively the strengths in our universities and national laboratories. Such cooperative efforts between our universities and the Department of Energy's National Laboratories are critical to the continued health and strength of our nation's research in basic nuclear science and in the training of scientists who are essential for a broad spectrum of basic and applied fields from nuclear and diagnostic medicine, environmental safety and restoration, nuclear energy to basic research. While nuclear research is emphasized, our National Laboratories have many other unique facilities which also significantly extend and complement research in many areas of physics, chemistry, biology, engineering and computer science. For example, one has at ORNL the Materials Characterization and High Temperature laboratories which are used by university scientists. Such full partnerships between national laboratories and universities must be rewarded through additional federal support in order to encourage the development of such full partnerships in other national laboratories.

The first partnership with ORNL was the UNISOR Consortium which began in 1971. At that time there were no user groups in nuclear physics at national laboratories which had their own scientists carrying out research. However, budgets were becoming tight and big expensive accelerators were needed to carry out forefront nuclear research. Since only a few such accelerators existed and fewer would be built in the future, many on-campus university nuclear programs would stop. This would be a serious blow to graduate education of nuclear scientists. Thus Vanderbilt initiated a proposal for the State of Tennessee to join with Vanderbilt University, the University of Tennessee and nine other primarily Southeastern universities to initiate a new research facility at Oak Ridge National Laboratory mainly for use by university scientists. The State of Tennessee and the universities provided 100% of the cost of the first isotope separator on-line to an accelerator in the U.S. They also pledged to provide 40% of the operating funds for the facility for five years. The acronym UNISOR stands for UNiversity Isotope Separator at Oak Ridge. Oak Ridge Associated Universities is the fiscal agent for the operating funds for the facility. The universities in partnership with the State of Tennessee and the ORNL have continued to add new equipment in the $100,000 to $300,000 range, such as a laser facility and low temperature nuclear orientation facility to open up new research opportunities. Another major initiative of UNISOR was to bring from Europe a theoretical physicist in nuclear structure research to help guide and interpret the results of the UNISOR research program. This was the initial step that led to a national center for theoretical nuclear structure research at ORNL.

In 1991 on the twentieth anniversary of the founding of UNISOR and the tenth anniversary of the Joint Institute for Heavy Ion Research, an International Symposium on

Reflections and Directions in Low Energy Heavy Ion Physics was held in Oak Ridge. Appendix A gives an overview of the work of the UNISOR Consortium which now includes universities in Texas, Oregon and Maryland, and Oxford University (England) as well as nine universities from the States of Tennessee, Georgia, Kentucky, Louisiana, Mississippi, and South Carolina. Of particular importance, the UNISOR Consortium pioneered the opening up of Oak Ridge National Laboratory for use by university faculty and graduate students.

In the late 1970's when the new Holifield Heavy Ion Research Facility (HHIRF) with a new 25 million volt heavy-ion accelerator (still the world's largest) was being built at ORNL, Vanderbilt and The University of Tennessee Knoxville moved their partnerships with the State of Tennessee and ORNL to a new level with the development of the Joint Institute for Heavy Ion Research which is described in more detail in Appendix B, taken from the 1991 conference. Quoting from Appendix B, "The Joint Institute for Heavy Ion Research (JIHIR) is a unique institution in the world of nuclear physics. Conceived at Vanderbilt University in 1975, it is the result of a joint effort of Oak Ridge National Laboratory (ORNL), the University of Tennessee (UT), and Vanderbilt University (VU) to build a special university-like visitor environment at a national laboratory. In the process, the success of the JIHIR has occurred because of a new type of relationship between universities and a national laboratory, and a special collaboration between the federal government and the State of Tennessee."

The new Holifield facility was initiated with a major change in direction for Department of Energy National Laboratories in nuclear physics - a facility located at a national laboratory but used by scientists from around the nation and the world, and not a national facility used by in-house scientists. The Joint Institute was conceived to help make Holifield a nationally used facility. It is operated by the University of Tennessee, Vanderbilt University and Oak Ridge National Laboratory. Beginning with $100,000 pledges each from Vanderbilt and the University of Tennessee, ORNL provided the remaining funds for the first Joint Institute building. Funds for the second building were $44,000 from UNISOR and $350,000 from the State of Tennessee, along with additional funds from VU and UT. The institute buildings now are valued at over one million dollars. These buildings provide on-site lodging, office space, computer terminal rooms, and secretarial support for outside visitors along with a conference center.

Shortly after the first Joint Institute building was completed, and the second building was in progress, Vanderbilt and the University of Tennessee approached then Governor Lamar Alexander about having the State of Tennessee provide annual operating funds for a visitors' program to complete our Institute in the fullest sense of the word. We stressed that with such funds our Joint Institute would become a center of excellence in higher education like the State of Tennessee had not had before, attracting renowned scholars to Tennessee from around the world. A year later Governor Alexander introduced his Centers of Excellence program in higher education. The largest such center is the Science Alliance between the University of Tennessee Knoxville and ORNL as discussed in Appendix C and described briefly below. As part of the Center of Excellence grant to the University of Tennessee, the Joint Institute receives annually $165,000 to go with $30,000 from the Physics Division of ORNL, $30,000 from the Department of Energy and $12,000 from Vanderbilt University.

In general, $150,000 to $200,000 has been spent without overhead in our Joint Institute visitors program. The Joint Institute was a major factor in making HHIRF by far more used by

outside scientists than any other DOE nuclear laboratory. During its last 10 years of full-time operation before shutdown to build the RIB facility, 640 scientists from 148 institutions including 200 graduate students and 38 undergraduates worked at HHRIF. In 1990 there were 59 graduate students who used Holifield for part or all of their Ph.D. work, a number five to ten times larger than at the other DOE national laboratory nuclear facilities. These visitors have had major impacts on the quality and quantity of research carried out by University and ORNL scientists at HHIRF. Of particular note, the Joint Institute made it possible to bring in world experts to help develop and make operational new pieces of equipment. Of special note, Holifield is now being rebuilt as the first US radioactive ion beam (RIB) facility. Most of the world experts in this area are in Europe. Over the last two years the Joint Institute has brought distinguished scientists from several European countries and from other U.S. laboratories to provide critical help to develop this new RIB facility.

Three other major efforts of the Joint Institute are: a) the hosting of international workshops and conferences, b) obtaining State and university funds to match DOE funds for new facilities, and c) helping develop the first nuclear structure theory center in the U.S. For example, to date over 35 conferences have been hosted at the Joint Institute Conference Center with over 2,000 scientists at these meetings. The Joint Institute initiated steps which led to DOE's joining to create a center for Nuclear Structure Theory in cooperation with ORNL, the University of Tennessee and the Joint Institute.

The partnership of Vanderbilt, the University of Tennessee, UNISOR universities, the State of Tennessee and ORNL - DOE has provided the opportunity for them to cooperate in the sharing of funds to build specific new facilities at Holifield. For example, a major new facility, a new generation recoil mass spectrometer (RMS) was conceived at Vanderbilt which raised $1,500,000 toward the $2,2000,000 cost from university and external sources. It was designed by scientists at Vanderbilt, Texas A&M and Idaho National Engineering Laboratory. This $4,000,000 facility will be the centerpiece for research with the new ORNL RIB facilities.

The new RMS and RIB combined are a premier research facility, unmatched anywhere in the world. In the last six years university and State of Tennessee funds for capital equipment have totaled over $2,000,000 overhead free. A list of major contributions is attached in Appendix D. In addition, through the UNISOR Consortium several hundreds of thousands of dollars have been provided by the universities in purchasing small items of equipment, and in providing free shop work to fabricate components such as ion sources for use at ORNL. UNISOR has provided over $1,500,000 of overhead free direct support for the operation of the facility. The State of Tennessee and Vanderbilt have provided over $2,000,000 over the last 11 years to operate the Joint Institute. The total of all university and state funds exceeds $6,000,000 (overhead-free) for the operation and development of the Holifield research program. In addition, even larger sums of money in a variety of science and engineering areas have been provided for targeted cooperative research between the University of Tennessee and ORNL through the Science Alliance, see Appendix C. But more important than money has been the enormous contribution in time and talents of university scientists both at home and in Oak Ridge to the development of the ORNL facilities and to the research there. Such true partnerships must be strengthened by rewarding laboratories and universities engaged with such partnerships with additional support if one is to encourage other such partnerships.

The tremendous success of the Joint Institute played a crucial role recently in the State of Tennessee's agreeing to provide $6,000,000 for a similar institute to support a proposed new neutron science facility if constructed at ORNL. Thus from modest beginnings of the State of Tennessee providing $90,000 in 1971 to match university contributions for the UNISOR project, the partnerships have matured and spread out to encompass support for a wide range of major research equipment and infrastructure facilities for scientists around the world.

Another outgrowth of the Joint Institute is the development of a Center for Computationally Intensive Physics. A cooperative proposal that includes funds from Vanderbilt, the University of Tennessee and ORNL won one of the Grand Challenge Awards in High Performance Computing to develop at ORNL one of the nation's major new high performance computer centers. This center is allowing university and laboratory scientists to address problems which are so complex and computer intensive that they could not be carried out with previous computer facilities. This cooperation has led to international conferences and new programs at Vanderbilt and UT in computational physics. Again, the success of one partnership opened opportunities to develop other new partnerships and important programs.

In 1984, as part of Governor Alexander's Centers of Excellence Program, a specific partnership, the Science Alliance between the University of Tennessee Knoxville and ORNL, was formed to promote scientific research and educational collaboration between UTK and ORNL. See Appendix C. Major features are the Distinguished Scientists and Collaborating Scientists Program with joint appointments involving shared costs. This is a broad-based program that includes many areas of physics, chemistry, engineering, biology and computer science. There are also funds for shared undergraduate and graduate programs and start-up funds for new projects. In addition to the major specific cooperative research efforts tied to the joint appointments, the Science Alliance also supports broad partnership ventures. The Joint Institute for Heavy Ion Research and many of the special research facility projects are supported through the Science Alliance. This program is an outstanding example of a specific partnership between a university and a national laboratory and of broad partnerships of national scope.

Finally, I would like to emphasize the importance of university-national laboratory partnerships to graduate education and research through a specific example. Over the last 35 years my research group at Vanderbilt has trained 70 postdoctoral fellows and over 50 Ph.D. students in experimental nuclear physics almost all of whom used the facilities at Oak Ridge National Laboratory for part or all of their training and Ph.D. thesis research. These scientists hold a wide range of positions in industry, hospitals, government agencies, national laboratories, colleges and universities. Our research, published in over 590 papers, has significantly advanced our understanding of the nucleus of the atom. Our specific example documents that our national laboratories are providing essential nuclear facilities for research of university faculty and graduate students in nuclear physics.

The partnerships between our universities, the State of Tennessee and the Federal Government have been established to help provide world class research facilities for Tennessee university and ORNL scientists as well as scientists nationally and internationally. Keeping and expanding such partnerships are essential to the health and strength of many of our nation's university programs which are training the future scientists and technical personnel our nation must have to ensure its economic strength.

From: Proceedings of The Symposium on "Reflections And Directions In Low Energy Heavy Ion Physics" Edited by J.H. Hamilton, H.K. Carter, L.L.Riedinger and R.L. Robinson (World Scientific)

Appendix A

UNISOR

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Discussion

UNISOR is more than a facility, it is a collaboration with a remarkable spirit that came into being more than 20 years ago. While it continues to be the focal point for the nuclear structure research of many of its original members, the consortium has also attracted new participants who have helped sustain its collaborative spirit while, at the same time, contributing new ideas and expertise. The resources of the member institutions, both material and intellectual, have led to a number of major initiatives which have kept UNISOR research at the forefront of the study of nuclei far from stability. This process continues to this day through plans for research with a state-of-the-art recoil mass spectrometer and, most recently, through plans for research using radioactive ion beams. In addition, UNISOR has provided a collegial, university atmosphere for the education of graduate students within the hi-tech environment of a national laboratory. To date, 21 graduate students have completed their thesis research at UNISOR (9 M.S. and 12 Ph.D.) and 19 more are in various stages of completion (4 M.S. and 15 Ph.D.).

The idea for UNISOR was conceived at Vanderbilt University in 1969 following the formation there in 1968 of a university-users steering committee, chaired by J. H. Hamilton, which was organized to assist the Oak Ridge National Laboratory in its effort to establish a heavy-ion accelerator facility (later named Holifield). Hamilton realized that with the availability of heavy-ion beams, placing an isotope separator *on-line* to the accelerator would open up new areas of nuclear structure research, particularly research on nuclei far from stability. One must keep in mind that in 1969 the situation *vis-a-vis* nuclear physics research was quite different than at present. There were no *users groups* to speak of, national laboratories kept to themselves, universities had their own in-house programs, and state governments did not put resources into national laboratories. It was Hamilton who conceived of the revolutionary idea that universities and state governments might combine to purchase and locate major pieces of instrumentation at a national laboratory and pledge to provide a sizeable fraction of the operating costs for an extended period of time.

UNISOR officially began in July 1971 when Emory University, Furman University, Georgia Institute of Technology, Louisiana State University, Tennessee Technological University, University of Alabama (Birmingham), University of Kentucky, University of Massachusetts, University of South Carolina, University of Tennessee, Vanderbilt University, and Virginia Polytechnic Institute and State University joined with Oak Ridge National Laboratory and Oak Ridge Associated Universities to form a consortium and to submit a proposal to the Atomic Energy Commission. In that proposal the universities and the State of Tennessee pledged to provide more than 40 percent of the initial capital funds ($550,000) and 40 percent of the operating funds ($150,000) for at least five years. Since the primary capital equipment item at that time was an isotope separator, the consortium chose the acronym UNISOR to stand for UNiversity Isotope Separator at Oak Ridge. Oak Ridge Associate Universities became the fiscal agent for the consortium, J. H. Hamilton of Vanderbilt was electe chairman of the UNISOR Executive Committee (one member from each of the participatin institutions), and E. H. Spejewski was selected to be the Director. The formal UNISOR dedicatio took place on June 19, 1972.

It is not intended here to discuss, in narrative form, the sequence of events that transpired during th development of UNISOR. That chronology is presented in another section. Also, sinc comprehensive discussions of the UNISOR research program are presented in other papers of thi volume, only a few highlights of the research program are presented here. This is done with a view to showing that UNISOR has maintained its position at the forefront of nuclear structure researc through the steady implementation of new instrumentation and new experimental techniques on a approximate five-year cycle.

The isotope separator was installed during the summer of 1972 and the first on-line work began on September 2 of that year. Complete spectroscopy (locating and quantifying all transitions and energy levels below about 1.5 MeV) was developed and quickly became the standard for spectroscopy a UNISOR. This type of research first revealed that in the lightest Hg isotopes (A=184,186,188, deformed states coexist with the near spherical ground state structures [J. H. Hamilton *et al.*, Phys Rev. Lett. 35, 562 (1975)]; and provided critical tests of then current theories and stimulated the development of new theories that yield shape coexistence at zero spin. These Hg isotopes continue to represent one of the classic examples of nuclear shape coexistence [J.M. Eisenberg and W. Greiner, Nuclear Models, third revised edition, vol. 1, 1987, pp 283-4]. In the mid-1970's, high-performance conversion electron spectroscopy based on electron-gamma coincidence correlations was developed. This innovation, in conjunction with complete spectroscopy, provided the detailed systematics of shape coexistence in the Z=82 region which revealed the connection between deformation and the occupation of intruder states (single particle states of higher shells): most notably the demonstration that intruder states have a minimum energy at mid-shell of the other kind of nucleon (e.g. in the Z=82 region for N=104) [A. G. Schmidt *et al.*, Phys. Lett. 66B, 133 (1977)]. Additionally, UNISOR research, in conjunction with in-beam spectroscopy work, first revealed deformations in the ground states of the light Kr isotopes comparable to the superdeformed bands reported in the A=130 and 190 regions (3:2 axis ratio) and described the origin of the deformation in terms of reinforcing shell-gaps. The term *superdeformation* was used in that paper [R. B. Piercey *et al.*, Phys. Rev. Lett. 47, 1514 (1981)].

The UNISOR collinear laser facility was installed in 1981 and quickly demonstrated that the collinear laser-ion beam configuration could be used to make precise measurements of atomic lifetimes [M. L. Gaillard *et al.*, Phys. Rev. A26, 1975 (1982)]; and to test the time dilation formula in special relativity to a few parts per ten thousand [P. Juncar *et al.*, Phys. Rev. Lett. 54, 11 (1985)]. By utilizing laser hyperfine structure measurements, UNISOR research proved and explained that the deformation in the light Tl isotopes increased with decreasing mass number even though the band structure remained unchanged [J. Bounds *et al.*, Phys. Rev. Lett. 55, 2269 (1985)]. Also, alpha-decay-rate measurements provided additional evidence that the Z=82 configuration may not be magic

(closure of the energy gap) for nuclei with N near the mid-neutron shell region [K. S. Toth *et al.*, Phys. Rev. Lett., 53, 1623 (1984)].

UNISOR research provided the early evidence that electric monopole transitions are associated with shape coexistence [E. F. Zganjar *et al.*, Hyp. Int. 43, 321 (1988)], and that precise conversion-electron-gamma coincidence spectroscopy is often required to extract this information [C. D. Papanicolopules *et al.*, Z. Phys. A330, 371 (1988)]. The utility and precision of the coincidence data, and all other types of on-line experiments as well, were greatly enhanced in the mid-1980s following major advances in ion-source efficiency which were initiated by H. K. Carter who became Director in 1985.

The UNISOR On-line Nuclear Orientation facility (based on a ^{3}He/^{4}He dilution refrigerator) began operation in June 1988. Of the four on-line facilities in the world, it is unique in that it enables one to measure to 4th order in the angular distribution, thus enabling one to obtain unique values for multipole mixing ratios. One of the important results from this facility, which has a bearing on shape coexistence and intruder states, involves multipole mixing measurements in ^{194}Pt. The results indicate that by combining conversion coefficient measurements with E2/M1 ratios, obtained from anisotropy measurements using the nuclear orientation facility, one is able to obtain the actual fraction of electric monopole strength in I^{π} to I^{π} transitions [Y. Xu *et al.*, Hyp. Int. (proceedings of the Second International Conference on On-Line Nuclear Orientation, Oak Ridge, TN, October 16, 1991), in press; and to be published].

It was decided in 1981 that UNISOR needed a theoretical component, and Georg Leander of Lund University was hired. This proved to be an exceptionally good choice and, until his untimely death in 1988, UNISOR researchers and graduate students enjoyed a most stimulating interweaving of experiment and theory. One of Leander's first major papers, which resulted from this interaction, involved the onset of deformation in the neutron-deficient Sm region [Phys. Lett. 110B, 17 (1982)]. One of his last papers, completed while he was ill, is a detailed treatise on the ideas of spontaneous symmetry breaking in the nuclear intrinsic frame [Phys. Rev. C37, 2744 (1988)]. Ragnar Bengtsson, also of Lund University, was hired in 1990 and he immediately began to fill the void left by the death of Leander. In 1991 Bengtsson organized the first of what will be a series of Hands-On Nuclear Structure Theory Workshops. This was an innovation greatly appreciated not only by nuclear structure theorists and experimentalists, but especially by the graduate students.

One of the things that makes the UNISOR consortium work so well is the large number of meetings, brainstorming sessions, and workshops that it organizes. These are too numerous (3 or 4 per year) to list in the chronology below, but one can give an example: In June 1988, an *in-house* workshop on on-line nuclear orientation was held at the Joint Institute with 41 participants comprised of 15 faculty members, four postdoctoral research associates, nine graduate students, and 11 staff members from five national laboratories (ORNL, INEL, ILL, LANL, NIST) and two from private laboratories.

Although UNISOR is a consortium with a membership of universities which contribute real dollars on an annual basis ($8,000 per university), and which contribute considerable resources in ancillary ways as well (e.g., human resources such as graduate students and postdoctorals, equipment items, and electrical and mechanical shop work), it nonetheless operates as an open users facility. A large number of experiments have been conducted at the facility by non-members, both from the United States and Europe. Some are done in collaboration with UNISOR member scientists and some are not. Any experiment which passes the scientific merit test of the Holifield Program Advisory Committee, and for which UNISOR has the capability, is carried out.

The UNISOR facility is unique in the United States in its ability to provide information on the low-energy, low-spin structure of nuclei far from stability which is not easily obtainable in other ways. Some examples include: ground state and isomeric state spins, precise magnetic moments, quadrupole moments (static deformation), nuclear *rms* radii, identification and classification (definite spins and parities) of both yrast and non-yrast states up to a few MeV, the precise determination of transition strengths and multipole mixing ratios, and the precise determination of the monopole mixing strength. At UNISOR, one is able to isolate nuclei in long-lived states (ground states and isomers with $T_{\frac{1}{2}} \geq 1$ sec) such that they can interact through their moments with selected environments. Such control over the nuclear many-body problem is unique.

Still, with all the experimental capability of the UNISOR facility, members of the collaboration continued to plan for the future. They joined with scientists from Vanderbilt, Idaho Nuclear Engineering Laboratory, and Holifield to help design and obtain funding for a new generation recoil mass separator. Construction of this instrument is to begin in 1992. It will be the World's most capable instrument of that type and, when operated on-line to a radioactive ion-beam accelerator, will enable UNISOR nuclear structure research to reach combinations of neutrons and protons which are presently unexplored. This will enable one to further test current theoretical ideas and, as happened on UNISOR's first trek far from stability, to uncover unanticipated new physics.

Successful operation of an initiative in which 14 institutions provide resources and which is located at a national laboratory requires an outlook quite different from that of either a university or a national laboratory. In making the consortium work so successfully for over 20 years, UNISOR is not only the first, but probably the best example of a users consortium. That the UNISOR collaboration continues to this day, while others have come and gone, is a tribute to those who created it and to those who have sustained it. It is also a tribute to the staff of the Holifield Heavy Ion Research Facility who provided a fertile environment in which UNISOR could thrive.

Notable Quotes

"In these days of austerity in the physical sciences, it's a particular pleasure to be able to point to a project that goes counter to that trend. UNISOR is remarkable, not only for its sheer existence, but also for the extraordinary measure of cooperation between so many institutions that it represents." - Alvin M. Weinberg, Director Oak Ridge National Laboratory. At the dedication, June 19, 1972.

"The number of young nuclear scientists involved is encouraging, and their vigor augurs well for the success of the program." - The first Advisory Committee Report, 1974.

"The UNISOR collaboration continues to impress the Advisory Committee in exhibiting an atmosphere of dedication and cooperation among the users. The UNISOR staff has continued to do an excellent mature job of facility development and operation. We are please to comment on the high quality of the experimental facility at UNISOR." - Advisory Committee report, 1976.

"The Advisory Committee is pleased to find a growing sense of maturity in the UNISOR collaboration. The level of skills of the users and the in-house staff continues to grow in a healthy manner. The spirit of cooperation among the members of the UNISOR consortium continues to impress us as a dominant factor in the many accomplishments to date at the facility. - Advisory Committee report, 1978.

"We view the research program of the UNISOR consortium to be healthy and vigorous. The program is developing the diversity necessary for a balanced approach to nuclear structure physics." - Advisory Committee report, 1979.

"In basic nuclear research, we have two outstanding success stories--the University Isotope Separator at Oak Ridge (UNISOR) and the Joint Institute for Heavy Ion Research." - Edward A. Friedman, Director Office of Energy Research, U. S. Department of Energy, 1980.

"The increasing diversity of the UNISOR program is very impressive." - Advisory Committee report, 1981.

"We see the scientific program at UNISOR maturing in a very satisfactory way. The last Advisory Committee saw the opportunity for HHIRF/UNISOR to become the l ading center of nuclear structure in the U.S. We see that this goal is nearer." - Advisory Committee report, 1984.

"If one does not want to neglect advanced scientific education at our universities, it is necessary to proceed as you here in Tennessee have demonstrated to the world in an exemplary way: You have initiated, very successfully, important steps in new directions of research, as was done with UNISOR, and created, with the heavy ion institute, an intellectual center and meeting place of unique character indeed." - Water Greiner, Symposium "Reflections and Directions in Low Energy Heavy-Ion Physics," Oak Ridge, TN, October 14, 1991.

Chronology

1968 A university users group steering committee for Oak Ridge National Laboratory was formed in March with J. H. Hamilton as chairman.

1969 The idea for UNISOR was conceived at Vanderbilt University in November.

- J. H. Hamilton (Vanderbilt University) and William Bugg (University of Tennessee) approached Alex Zucker (Associate Director, ORNL) and Robert Livingston (Director, ORNL Electronuclear Division) about the UNISOR concept.

- Hamilton and Bugg approached Tennessee's Governor Buford Ellington for support.

1970 Hamilton and Bugg requested William Pollard (Executive Director, ORAU) to assist with the complex organizational structure involved in forming a consortium of public and private universities, a national laboratory, a state government, and a federal agency.

- The first of a series of bi-monthly meetings of the founding UNISOR members began in February and continued throughout 1970.

1971 UNISOR officially came into being in July, with the signing of memoranda of understanding between the universities and ORAU and with the submission of a research proposal to the Atomic Energy Commission.

1972 Eugene Spejewski became the first permanent UNISOR Director and Ronald Mlekodaj the first staff scientist.

- ORAU, with Executive Director Pollard's considerable help, became the fiscal agent for the UNISOR research contract with the Atomic Energy Commission.

- The UNISOR wing to the Oak Ridge Isochronous Cyclotron building was completed in January.

- The UNISOR isotope separator was delivered in April.

- The UNISOR dedication took place on June 19.

- The first successful on-line test of the isotope separator took place in September.

1974 H. K. Carter was hired as the second staff scientist after two years as Research Associate.

- A three-person Advisory Committee and formal Information Meetings were established.

1976 Two additional beamlines were added to the isotope separator.

- The University of Massachusetts withdrew from membership.

1979 The conference "Future Directions in Studies of Nuclei Far From Stability" was organized by UNISOR (J. H. Hamilton conference chairman) and held at Vanderbilt University.

- The proposal for a UNISOR laser facility was submitted to the U. S. Department of Energy.

1981 The UNISOR laser facility became operational.

- The UNISOR lab flooded (approximately 4 feet of water) because of a broken water main.

- Emory University withdrew from membership.

- Georg Leander was hired to be the UNISOR theorist.

1982 The conference on Lasers in Nuclear Physics was co-sponsored by UNISOR.

- Virginia Polytechnic Institute and State University withdrew from membership.

UNISOR's tenth anniversary was celebrated at the SESAPS meeting in Lexington, Kentucky, October 28, 1982.

1983 A group of UNISOR scientists traveled to Louvain, Belgium to participate in an on-line nuclear orientation experiment.

- Mississippi College joined UNISOR.

1984 Funds were acquired to purchase an Oxford Instruments dilution refrigerator for the UNISOR nuclear orientation facility.

- UNISOR graduated from its "temporary" quarters in the trailers and moved to the newly completed second building of the Joint Institute for Heavy Ion Research.

1985 Eugene Spejewski resigned as director to take an administrative position at Oak Ridge Associated Universities. Ken Carter was appointed Director.

- The University of South Carolina withdrew from membership.

1986 The ^{3}He/^{4}He dilution refrigerator was ordered from Oxford Instruments.

- Ron Mlekodaj resigned as staff scientist to take a position with Oak Ridge National Laboratory.

- The University of Alabama (Birmingham) withdrew from membership.

1987 Oregon State University joined UNISOR.

- The University of Maryland joined UNISOR.

- Modernization of the isotope separator was initiated.

1988 The Executive Committee authorized the purchase of a new UNISOR data acquisition system based on a Digital Equipment Microvax Computer and Nuclear Data front-end and software.

- The ^{3}He/^{4}He dilution refrigerator and associated beam lines which make up the UNISOR nuclear orientation facility were installed.

- Georg Leander died on May 17. His last major paper, a detailed treatise on the ideas of spontaneous symmetry breaking in the nuclear intrinsic frame, was completed during his illness. [Phys. Rev. C37, 2744 (1988)].

- A five-person Advisory Committee was established.

- The first successful test of the nuclear orientation facility took place on June 29.

1989 Mississippi State University joined UNISOR.

- Texas A&M University joined UNISOR.

1990 Ragnar Bengtsson was hired as the UNISOR theorist.

- Paul Mantica was hired as staff scientist.

1991 Symposium "Reflections and Directions in Low Energy Heavy-Ion Physics to celebrate the 20th anniversary of UNISOR and the 10th anniversary of the Joint Institute was held at the Joint Institute in Oak Ridge on October 14-15.

Organization

Founding Institutions

Emory University
Furman University
Georgia Institute of Technology
Louisiana State University
Oak Ridge Associated Universities
Oak Ridge National Laboratory
Tennessee Technological University
University of Alabama (Birmingham)
University of Kentucky
University of Massachusetts
University of South Carolina
University of Tennessee
Vanderbilt University
Virginia Polytechnic Institute & State University

From: Proceedings of The Symposium on " Reflections And Directions In Low Energy Heavy Ion Physics"

Edited By

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(World Scientific)

JOINT INSTITUTE FOR HEAVY ION RESEARCH

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I. Introduction

The Joint Institute for Heavy Ion Research (JIHIR) is a unique institution in the world of nuclear physics. Conceived at Vanderbilt University in 1975, it is the result of a joint effort of Oak Ridge National Laboratory (ORNL), the University of Tennessee (UT), and Vanderbilt University (VU) to build a special university-like visitor environment at a national laboratory. In the process, the success of the JIHIR has occurred because of a new type of relationship between universities and a national laboratory, and a special collaboration between the federal government and the State of Tennessee. A Memorandum of Understanding was signed in 1982 to complete in a formal way what had started several years earlier, i.e., a cooperation and then an Institute to promote the well-being of the centerpiece of the tripartite interest, the Holifield Heavy Ion Research Facility (HHIRF). The Joint Institute support of the Holifield mission has occurred in five major ways:

1. a vigorous visitor's program, especially emphasizing nuclear structure theory;

2. on-site free sleeping and kitchen accommodations for the many experimentalists involved in Holifield measurements;

3. sponsorship of a large number of conferences, workshops, and meetings on a variety of topics;

4. direct support of the Holifield experimental program via the sponsorship of visitors dedicated to the construction or implementation of certain experimental tools and also the establishment of a mechanism for finding non-federal funds to match those of the Department of Energy for the construction of new experimental devices at Holifield; and

5. office and laboratory space and secretarial support for the faculty, postdoctoral associates and graduate students from the two member universities, and from the universities in the UNISOR consortium.

The purpose of this paper is to recount the history of JHHR over the past decade, to review its programs in recent years, and to look forward to the role of this institute in the future evolution of Holifield. It is hoped that the successes of the Joint Institute will provide a model for future examples of university-national laboratory collaborations.

II. Beginnings

The idea for a visitor's institute in support of Holifield grew in part form the early successes of the UNISOR collaboration (as discussed in the previous paper). UNISOR was established in 1971 to purchase and support a mass separator on-line to the Oak Ridge Isochronous Cyclotron (ORIC). The rapid implementation of the UNISOR eleven-member consortium proved that this close university-national laboratory relationship could evolve and serve as a model for the increasingly user-oriented extension of national laboratories in the 1970s. When HHIRF was funded by the Department of Energy in 1975, it was with the expressed understanding that there would be a new direction in nuclear physics. That is, Holifield was to be a facility located at a national laboratory but used by scientists from universities and laboratories around the country and world, and not a national laboratory facility used essentially by the in-house scientists. This signaled a major change in policy and led ORNL to appoint five scientists to a national advisory board to oversee the planning and construction of HHIRF, to ensure that it became a truly national facility. While serving on that panel, one of us (JHH) conceived of a Joint Institute to help ensure university scientists ready access to HHIRF. Soon after, Chancellor A. Heard (VU) accepted this unusual idea and pledged $100,000 toward the construction of a users building. The University of Tennessee soon thereafter pledged $100,000, followed by ORNL providing the additional funds for the first Joint Institute building. Even so, lengthy negotiations were held with Oak Ridge-DOE Operations before approval was received for this new cooperative venture. Shortly thereafter, the central administration at Vanderbilt University began providing $10,000 annually to fund visitors to this rapidly building heavy-ion program.

The first construction of this dedicated space adjacent to HHIRF began in 1980. Building 6007 was completed by the laboratory at a cost of $439,000, including $200,000 given by Vanderbilt and the University of Tennessee. This building opened in 1981 as user space, containing nine offices, seven sleeping rooms, and a kitchen and lounge area. The sleeping capacity of Building 6007 was later increased to twelve by conversion of some offices to sleeping rooms. The proximity of this building to Holifield, coupled with the absence of a nightly charge, has made this an extremely important aspect of user activity at Holifield. It is clear that many fewer graduate students would have been able to participate in Holifield research if this dormitory space had not been provided. Besides helping make the laboratory user-friendly for outside scientists, the institute helped to significantly enhance the scientific training of graduate students. As faculty researchers have emphasized, not only can they afford to bring there beginning graduate students for experiments, but more importantly, in the evenings the senior scientists and graduate students gather in the institute lounge to discuss the results of the day's efforts and problems, and their hopes for the experiment Such in-depth discussions clearly enhance the research while providing graduate students with invaluable training.

Building 6007 was designed by H. Shapira of ORNL also as an experimental facility for research on energy efficiency. Consequently, there are special energy-saving features, such as the fact that one side and the roof of the building are underground.

In 1980, there also began an effort to convince the government of the State of Tennessee to fund another building at Oak Ridge to provide additional space for user programs and needs. Leaders of Vanderbilt University made initial approaches to state legislators and the governor about this. Indeed, the circumstance of a private university approaching state government for funds to benefit a national laboratory is an unusual one. Soon thereafter, support from leaders of the University of Tennessee provided a unique partnership of public and private universities in Tennessee in pursuit of a common scientific goal. This double-barreled lobby effort resulted in a 1981 appropriation by the state of Tennessee of $350,000 toward the construction of a second Joint Institute building (Bldg. 6008) at ORNL. In subsequent months, the Oak Ridge Associated Universities added $44,000 to the project to enlarge the design of the building and, thereby, provide space for UNISOR personnel. The two universities provided additional funds for furniture for the second building.

The state appropriation of funds for a new building at Oak Ridge necessitated the writing of a land-lease agreement between UT/State of Tennessee and the Department of Energy. Over two years of discussions and negotiations involving attorneys at UT, ORNL, DOE, and the State of Tennessee resulted in the signing of the land-lease agreement in 1982. A prolonged period of negotiation was necessary since this provided one of the first examples (if not the first) of a state leasing federal land for the construction of a state building, at least in the southeastern United States. It is possible that in the legal climate of 1992, a far greater amount of time would be needed for such a negotiation.

The Memorandum of Understanding between ORNL, UT and VU was signed also in 1982. This formally initiated what had begun earlier, the cooperation to operate the Joint Institute for Heavy Ion Research. This Memorandum established a Policy Council composed of one member from each institution. The Policy

Council first met in early 1983 and was composed of Associate Director Alex Zucker (ORNL), Chancellor Jack Reese (UT), and Provost Wendell Holladay (VU). These three leaders then appointed Russell Robinson, Lee Riedinger, and Joe Hamilton who are shown in Fig. 1 to serve as the institutional representatives on the Policy Council in the future, and designated Hamilton as the first director of the Joint Institute.

The construction of the second building of the Joint Institute began in the fall of 1983 after a year of assessment of needs and design of the structure. The construction was administered through the Facilities Planning Group at UT. Construction was finished in May of 1984, at which time occupation of the structure began. The Joint Institute buildings are shown in Fig. 2.

Fig. 1: Members of the Joint Institute Policy Council 1984-91 (left to right, L.L. Riedinger, R.L. Robinson, and J.H. Hamilton).

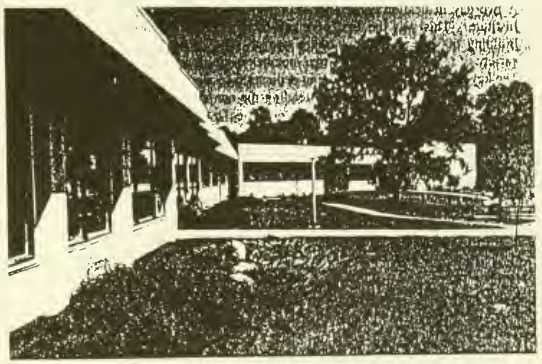

Fig. 2: The Joint Institute physical plant.

Funds for the construction of Building 6008 (the new state owned building) came before the funds to actually operate the Joint Institute were identified. An initial request was made by UT and VU to the state of Tennessee to operate the institute with a visitors program as a new type of center for higher education in Tennessee. This problem was later solved when the Science Alliance program was established at UT in the summer of 1984. The State of Tennessee, under the leadership of then Governor Lamar Alexander and then Speaker of the House Ned McWherter, established a Center of Excellence program as part if its new package of support for education. A competition was held for proposed centers of excellence throughout the higher education system in Tennessee. The Science Alliance was the winner of the first and the largest of these Center of Excellence grants. Its purpose has been to increase the level of the scientific programs at UT through a closer connection with sister programs at ORNL. In view of the long-time collaboration between the two institutions in nuclear physics, it was possible to establish the Joint Institute as a cornerstone of the Science Alliance. In July 1984, the first annual budget was established for the Joint Institute, composed of $165,000 from the Science Alliance, $30,000 from the Physics Division of ORNL, $30,000 from the Department of Energy, and $12,000 from Vanderbilt University.

A two day dedication conference was held in October of 1984 at the new Joint Institute. This was the first of many conferences and workshops to occur in Building 6008 over the next seven years. The dedication was attended by a variety of top officials of the three member institutions and of state government. The keynote speaker of the opening dedication session was Nobel Laureate Glenn Seaborg. Some of the officials attending the conference are shown in Fig. 3.

Fig. 3: Dignitaries who spoke at the opening dedication of the first building of the Joint Institute (left to right, Joe LaGrone, DOE Oak Ridge; Joe Wyatt, Chancellor, Vanderbilt University, Glenn Seaborg, University of California; Joe Hamilton, Vanderbilt University; Herman Postma, Director, ORNL; Representative Marilyn Lloyd of Tennessee; Jack Reese, Chancellor, University of Tennessee; Ed Boling, President, University of Tennessee; and Wilmot Hess, U.S. DOE)

III Visitor Program

The core of the Joint Institute activities is a large vigorous program of scientifi visitors. In most years, a total of $150,000 to $200,000 is spent in an overhead free manner on visitors. These funds have been amplified in many cases by usin them as matching funds for other sources of support, such as sabbatical leave Each year there is an intentional split between visitors coming for a very shor period (for several days to attend a workshop or work with resident programs) those for a term of medium length (one to three months), and those for a lon term (one or more years). Since the inception of the Joint Institute, there has bee a total of over 450 visitors drawing at least partial support of their expenses fro institute funds. During the three years, 1988-90, over 50 scientists each yea spent an average of over two months working at the Joint Institute.

Examples of areas in which the Joint Institute guests have had an impact ar discussed below:

a) Nuclear Structure Theory

A natural area of support for the Holifield experimental program is in nuclear structure theory. A high level of interaction has developed between resident experimentalists and visiting nuclear structure theorists. Some have made regular pilgrimages to the Joint Institute, e.g., Walter Greiner of Frankfurt, Ricardo Broglia of Copenhagen/Milano, Amand Faessler of Tübingen, Fritz Dönau of Rossendorf, Claude Mahaux of Liege, Da Hsuan Feng of Philadelphia, Yong-shou Chen of Beijing, Jing-ye Zhang of Lanzhou, and Joachim Maruhn of Frankfurt. Others have spent a year or more working at the Joint Institute, e g , Jerzy Dudek of Strasbourg, Witek Nazarewicz of Warsaw, Ramon Wyss of Stockholm, Paul Semmes now of Tennessee Technological University, and Zhang from Lanzhou. Although the work of this distinguished group of visitors is widely varied, one can point out several significant emphases:

1. Mesh calculation of nuclear shapes. Short visits by Nazarewicz and Ragnar Bengtsson (then from Lund) in 1985 established a program for detailed self-consistent calculations of the nuclear shape as a function of rotational frequency. An array processor was purchased for the Physics Division VAX computer, this opened the possibility of a unique and massive set of calculations. Zhang visited the Joint Institute for a year and carried out a huge number of calculations on nuclei in the rare-earth region of deformation. These were the first such systematic calculations over a wide range of nuclei, and they provided

a significant focus of interaction in subsequent years between experimentalists and theorists. This focus has been re-established by the extended visits of Nazarewicz and Wyss to the Joint Institute in the last year.

2. Ongoing FDSM interests. Another nuclear structure focus has been the Fermion Dynamical Symmetry Model, developed partially through Joint Institute support. Mike Guidry of the University of Tennessee has worked closely with JIHIR visitors, e.g., Cheng-li Wu (Jilin in China) and Da Hsuan Feng (Drexel), to make remarkable advances in the predictive powers of this model in recent years.

3. Generator Coordinator Method (GCM). Joint Institute visits by Dönau and Zhang have led to much progress in the use of GCM techniques to explain dynamical aspects of nuclear collective motion.

4. Hands-on Theory Workshop. In the summer of 1991, a unique approach to accessibility to nuclear models was tried successfully. Over 40 nuclear physicists (mostly experimentalists and many at the graduate student level) attended a two-week workshop to learn the operational details of collective nuclear models. This appruach will be used as the model for a very similar workshop in Copenhagen in 1992.

5. Superdeformation. Jerzy Dudek carried out extensive calculations which exposed the unexpected regions of hyperdeforma tion. His calculations were one of the major scientific justifications in the proposal that led to the funding of Gammasphere. Chapter 3 on Scientific Justification in the Gammasphere Proposal began with a discussion and a figure of Dudek's calculations of ^{152}Dy, including superdeformed and hyperdeformed potential minima.

6. Theoretical calculations in support of experimental studies. Many of the theorists have often worked closely with experimental groups to provide calculations and theoretical analyses of experimental results. These cooperations have led to significant impact on the experimental programs by suggesting additional studies or the investigation of new phenomena. At the same time, the new experimental data often have provided confirmation of the theoretical calculations as well as stringent tests that have called for further development of the models. This interplay, often day by day, of theory and experiment has indeed been one of the exciting and fruitful contributions of the Joint Institute.

7. Support of the Theoretical Program: Theory month. One of the activities that has been supported by the Joint Institute for more than five years is Theory Month. This is a one-month period when a number of nuclear theorists are invited to spend a month at the Joint Institute. Typically, between four and six theorists are invited to participate. Activities for Theory Month consist of seminar series, colloquia, and small workshops. This is a time of in-depth discussions and exchanges of ideas with scientists from around the world. The principle focus has been the support of nuclear structure and related programs. Theory Month has been remarkably successful. Included among the visitors have been J. Maruhn (Frankfurt), C. Mahaux (Liege), M. Nagarajan (Dareshury), and D. Brink (Oxford).

h) Support of the Experimental Programs

Significant Joint Institute visitor support has benefited the experimental Holifield program. One mechanism for this has been the support (full or shared) of physicists brought to help in the development of large pieces of Holifield equipment. Among these have been:

1. Cem Girit, 1987-89, to lead in the installation of the liquid-helium dilution refrigerator at UNISOR;

2. Dennis Hamilton, 1989, for the same purpose;

3. Ken Teh, 1987-89, to work on the development of the Heavy Ion-Light Ion (HILI) facility, a large array of charged-particle detectors;

4. Mark Riley, 1986-88, to assist in implementation of improvements in the Spin Spectrometer (and use of the Compton suppression Ge array);

5. Jim McNeill, 1989-90, for the same purpose.

c) Atomic Physics

Although the dominant focus of JIHIR has been heavy-ion nuclear physics, some support has benefited the heavy-ion atomic program. Visitors to work with the atomic program of Sheldon Datz and Ivan Sellin have been regularly supported, e.g., K. Groenefeld from Frankfurt, R. Schuch, Stockholm, and K. Komaki, Tokyo.

IV. Conferences, Workshops, and Meetings

A key mission of the Joint Institute is to bring scientists together in a highly interactive mode. The organization and sponsorship of a large number of workshops and conferences have had a large impact on nuclear (and to some extent atomic) physics. Table I contains the list of 31 conferences and workshops sponsored partially or wholly by the Joint Institute since 1984. All but one have taken place in the Institute and most have been organized or implemented by Joint Institute staff. These cover a broad range of topics. Eleven were based on equipment, where physics and hardware details relating to a new piece of apparatus or accelerator were discussed. Featured topics have been Gammasphere, nuclear orientation devices, recoil mass spectrometers, storage rings, and Monte Carlo computer codes. Five of the 31 workshops have been based on issues of nuclear theory, e.g., the Hands-On Theory Workshops discussed above. Those aspects of JIHIR activity, especially, has put a heavy load on the Institute staff. The success of these conferences has been to a large part due to the work of Jackie Smith, with the more recent addition of the talents of Carlene Stewart.

TABLE I

Meeting	Date	Attendees
Directions in Nuclear Structure Research/Dedication Ceremony	10/15-16/84	107
Workshop on Atomic Physics with Stored Cooled Heavy Ion Beams	1/13-15/86	50
Recoil Mass Spectrometer Workshop	6/23-24/86	50
Workshop on Heavy Ion Physics and Instrumentation for a 15-Tm Booster and Storage Ring	10/2-4/86	65
Holifield Theory Users Group	9/25-26/87	53
UNISOR Executive Committee Meeting	11/18/87	29
Workshop on the Proposal for a National Gamma-Ray Detector Facility	11/19-21/87	90
Computational Atomic & Nuclear Physics at One Gigaflop	4/14-16/88	52
UNISOR Workshop	6/21/88	45
Workshop on High Energy Nuclear Collision Monte Carlo Codes	9/12-23/88	18
Workshop on Microscopic Models in Nuclear Structure Physics	10/3-6/88	75
Town Meeting on High Energy Heavy Ion Physics	4/24-25/89	92
UNISOR Executive Committee Meeting	6/19,23/89	50
UNISOR Nuclear Orientation Workshop	6/20-23/89	55
Summer School of Computational Atomic and Nuclear Physics	7/2-13/89	72
Planning Workshop for Gammasphere	9/21-22/89	82
HHIRF Theory Users Group Meeting	3/23-24/90	46
Gammasphere Steering Committee Meeting	4/22/90	12
International Conference on Nuclear Structure in the Nineties	4/23-27/90	208
Second UNISOR Nuclear Orientation Workshop	7/31-8/2/90	33
Radioactive Beams at the HHIRF	10/2/90	40

Gammasphere Meeting	11/2/90	21
Future Forms of Collaboration Between Theorists and Experimentalists in the Field of Low Energy Nuclear Structure	2/26/91	52
Lectures on Hands-On Nuclear Structure Theory Workshop	8/5-16/91	49
Symposium on Reflections and Directions in Low Energy Heavy-Ion Physics	10/14-15/91	85
International Conference On-Line Nuclear Orientation-2	10/16-19/91	75
International Workshop on Nuclear Structure Models	3/16-25/92	65
Symposium on Nuclear Reactions "Satchlerfest"	4/15-16/92	50
Planning Committee Meeting for Radioactive Ion Beams Conference	5/28-29/92	35
Symposium on Nuclear Physics of the Universe	9/24-26/92	
Workshop on the Production and Use of Intense Radioactive Ion Beams at the IsoSpin Laboratory	10/6-10/92	

V. Mechanism for Matching Funds

An important recent aspect of the funding of large pieces of equipment has been the emphasis on local funds matching the federal monies. The Joint Institute was created from that spirit of partnership in Tennessee, and its existence allows opportunities to raise more funds for initiation of new projects. In a sense, not only has the Joint Institute brought visibility and expanded possibilities to our university programs, but also it has bought a higher responsibility to UT, Vanderbilt and the State for the health of nuclear physics programs at Holifield. This has led to a large amount of local support for specific detectors at Holifield:

a. Array of Compton-suppressed Ge detectors: $1.2 million total cost, including $125,000 from Vanderbilt and $320,000 from the University of Tennessee (through the Science Alliance program);

b. Spin Spectrometer electronics upgrade: $40,000 contribution from the Science Alliance at UT;

c. Liquid helium refrigerator: $15,000 from Vanderbilt, $75,000 from the UT Science Alliance;

d. Electronics for a neutron detector: $40,000 from Vanderbilt;

e. Compton polarimeter: $30,000 from Vanderbilt;

f. Recoil Mass Spectrometer: $500,000 from the State of Tennessee, $155,000 from the UT Science Alliance, and $155,000 from Vanderbilt;

g. Radioactive beam facility development: $100,000 each from UT and Vanderbilt.

In addition to the above list of expended funds, the State of Tennessee had committed $800,000 towards the cost of construction of Gammasphere if it had been sited in Oak Ridge.

VI. Conclusions

The Joint Institute for Heavy Ion Research has proven to be a very successful entity of collaboration centered around the Holifield facility, including collaborations between nuclear physicists (experiment and theory), between universities and a national laboratory (University of Tennessee, Vanderbilt University and Oak Ridge National Laboratory), and between state and federal government. It is a real center of activity, serving not only as a host for its visitors and conferences but also a site for most ORNL Physics Division luncheon meetings, seminars and colloquia. It is, in a real sense, university space at a national laboratory, and thus serves as a center of activity for faculty, postdocs, and graduate students. It provides an on-site dormitory and kitchen, which has allowed university groups to bring to experiments far more students than normal, and it is a fine model for new joint activities, whether in nuclear physics or in other fields of science. Indeed other "Joint Institutes" have been or are being born between two or three of the JIHIR members, one

in Energy and Environment and another in Computational Science. Another will arise in the future with the anticipated Advanced Neutron Source at Oak Ridge as the centerpiece.

Changes occur in all entities, the Joint Institute and Holifield being no exceptions. At the Joint Institute, the Policy Council that has been intact from the beginning is changing, as Lee Riedinger (who served as director for four years) because of new administrative responsibilities has been replaced by Carrol Bingham. At Holifield, a change to a radioactive ion beam facility has begun. This change will be supported by the Joint Institute, and a new emphasis on nuclear astrophysics will be found in future visitor and conference programs. The next Joint Institute Workshop is on nuclear astrophysics in September, 1992. It is clear that the combined strength of Holifield and the Joint Institute can continue to provide much to the nuclear structure community in the coming decades, as it has in the past, and expand into new areas. Indeed the strong interplay between theory and experiment made possible by the Joint Institute will be even more important in the years ahead, as more exotic nuclei (to even beyond the proton drip line), new phenomena like hyperdeformation, and other unexpected phenomena are explored at the Oak Ridge Radioactive Ion Beam Facility.

VII. Acknowledgements

The authors wish to acknowledge the strong support of a number of key individuals: Alex Zucker, Associate Director, ORNL; James Ball, Director of ORNL Physics Division; Presidents Ed Boling and Joe Johnson, University of Tennessee; Chancellor Jack Reese, University of Tennessee; William Bugg, Head of the UT Physics Department; Connie Haynes, Science Alliance secretary in UT Physics; Thomas Callcott, Director of the UT Science Alliance; Ken Carter, UNISOR director; Chancellors Alexander Heard and Joe Wyatt, Vanderbilt University; and Dean Jacque Voegeli, Vanderbilt University.

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Appendix C

A Center of Excellence at the University of Tennessee UT/ornl science alliance

Oak Ridge Summit on Science, Environment, and Technology - June 1-2, 1995

Sharing Resources Creates Opportunity - Alliances that get you more for your research dollar

Attempts to establish formal links between The University of Tennessee, Knoxville (UTK) and Oak Ridge National Laboratory (ORNL) date back at least 30 years. The UT/ORNL Science Alliance is the best-known and most-enduring and successful of these. It was established in July 1984 as part of Governor Lamar Alexander's "Better Schools Program," which ratified similar Centers of Excellence at universities throughout Tennessee. The Science Alliance is the largest of these, with an annual budget of $3.5 million. This figure represents over 20 percent of the state's annual budget for such centers.

The primary mission of the Science Alliance is to promote scientific research and educational collaboration between UTK and ORNL. It does so through Distinguished Scientist and Collaborating Scientist programs, joint institutes, graduate and post graduate funding, faculty awards, and start-up support for new projects. The Science Alliance is the primary vehicle through which UTK and ORNL share personnel, specialized instruments, and financial resources to achieve mutual goals.

HISTORICAL PERSPECTIVE

Several issues converged in the late 1970s and early 1980s to bring about the Science Alliance. Reports from the Energy Research Advisory Board and the Federal Laboratory Review Panel had identified weak links between universities and the major federal research institutions, a condition both groups found "alarming," especially if the United States intended to continue world-wide scientific leadership.

"At a time when America is looking for ways to emphasize science and technology," wrote, then Governor Lamar Alexander in a March 1983 letter to Secretary of Energy Donald Hodel, "[a] coalition between a U.S. world class laboratory and our state's comprehensive research university will be a national milestone."

Equally important to science faculty and administration at UTK was the need to improve the national ranking of their graduate education and research programs. In the decade prior to 1984, laboratories at UTK had suffered from decline in state and federal appropriations for major equipment. The Science Alliance provided the means to improve this situation, not only attracting top level scientific expertise to joint UTK and ORNL positions but also drawing matching external funds for new science initiatives and improvements to facilities.

THE DISTINGUISHED SCIENTIST PROGRAM

Plans for a formal alliance actually began with the Distinguished Scientist Program. As originally conceived, the program was to include up to 30 esteemed scientists holding joint positions and be administered by one of Tennessee's Centers of Excellence. Thus, when the Science Alliance formally opened in July 1984, Dr. Gerald Mahan, a solid state physicist, was already hired, arriving that August. This spring, that hire paid huge dividends when Mahan became UTK's first member of the National Academy of Sciences. Mahan's

induction to the National Academy is his reward for sustained excellence and prominence in science, and much of that work was done with the support of the Science Alliance Distinguished Scientist Program.

During the years that followed, the Science Alliance continued to seek out scientists of similar caliber, adding such highly respected faculty/scientists as environmental microbiologist Dr. David White (hired in 1986), a recent winner of the coveted Clarke Prize, which, along with it's decorative gold medal, carries a $50,000 stipend; computer scientist Dr. Jack Dongarra (1989), author of the award-winning PVM software, which helps scientists aggregate their computing resources; Dr. David Joy (1987), known internationally for his work in electron and X-ray microscopy and electron holography; analytical chemist Dr. Georges Guiochon (1987), a recent Humboldt Senior Scientist who wrote the book on chemical separation techniques with his pioneering work in gas and liquid chromatography; Dr. Bernhard Wunderlich, (1988) chemical thermodynamics of solid state polymers, winner of the 1993 Prize for Applied Chemical Thermodynamics from the Swiss Society for Thermal Analysis and Calorimetry, an award rarely given to scientists outside of Europe; Dr. Ward Plummer, (1992) subatomic surface structure of materials, whose ability to organize national and international collaborations has brought new funding and science to East Tennessee; Dr. Peter Cummings (1994), a chemical engineer whose computer simulations predict how molecules in fluids interact and change as other substances are added or removed, saving the expense and time of repeated preliminary experimentation. Today, 12 distinguished researchers hold joint UT/ORNL posts. UTK provides 50 percent of the program's budget through the Science Alliance; the other 50 percent is provided by ORNL from U.S. Department of Energy funds. The appointments include a sizeable fund for graduate student and postdoctoral support, based at both UTK and ORNL.

COLLABORATING SCIENTISTS

The Collaborating Scientists Program makes it possible for UTK and ORNL to share scientists at all levels, who are already employed by one of the two institutions. Like distinguished scientists, collaborating scientists have access to the resources of both institutions, saving UTK and ORNL the time and money of duplicate efforts. Unlike the distinguished scientists, collaborating scientists are based in a home institution either at ORNL or UTK, and spend an agreed upon percentage of their time at the other institution. To date, eight scientists have joined the program, including three physicists, a computer scientist, a mechanical and aerospace engineer, an environmental economist, a library and information scientist, and a mathematician.

JOINT INSTITUTES

Science Alliance-supported research institutes bring together researchers from UTK, ORNL, Vanderbilt University, and other private and public organizations around the world. In all, the center supports four of these, the Joint Institute for Heavy Ion Research (JIHIR) being the oldest. Established in 1984, JIHIR led UTK and ORNL to international prominence in nuclear structure physics. Housed in two buildings adjacent to ORNL's Holifield Radioactive Ion Beam Facility (HRIBF) [formerly known as Holifield Heavy Ion Research Facility], JIHIR conducts conferences and workshops and sponsors research of visiting scientists. As the field of nuclear physics has changed, so has the Holifield facility and JIHIR. Currently, the Holifield is being converted into the country's first radioactive ion beam accelerator, a change that will expand JIHIR research into astrophysics and formation of elements.

In it's role as catalyst, the Science Alliance recently provided matching seed funds to the new Institute for Rare Isotope Measurements, enabling its director to secure substantial external funding from both the National Science Foundation and the U.S. Department of Energy. Similarly, the Joint Institute for

Computational Science (JICS), which was initiated with funds from the Science Alliance, now receives more than half of its total funding from other sources.

Referring to itself as the "friendly interface between researchers and parallel computing," JICS has become Tennessee's principal resource for training faculty, staff and graduate students in parallel computing. Established in 1991, JICS brings together skilled parallel computing specialists with interdisciplinary research scientists. Research includes collaborations with ORNL and UTK physicists, chemists and biomathematicians. Parallel computing cuts the time to execute a program from days or weeks, to a matter of minutes or hours. The powerful UTK and ORNL combined portfolio includes a MasPar MP-2, Thinking Machines CM-5, Kendall Square KSR1, and an Intel iPSC/860.

OTHER PROGRAMS

The Science Alliance also promotes East Tennessee's scientific excellence in a number of smaller ways. For example, graduate student supplements account for over $500,000 of the annual Science Alliance budget, providing assistance to approximately 100 students who do research at both UTK and ORNL. These stipends are crucial because they allow UTK science departments to compete with the nation's top universities for outstanding graduate students. In addition, each year approximately 80 undergraduates come to East Tennessee to study in UTK or ORNL laboratories through the Summer Research Fellows Program. For most, this is their first exposure to a high-level research environment, and the experience is a strong inducement to pursue graduate study in the sciences.

Science Alliance Faculty Research Awards have helped to recruit and retain top quality faculty in East Tennessee. Initiated in 1985, these awards provide annual recognition and financial incentive to top UTK science faculty. Financial support for the program comes from UTK central administration. Steadily improving applications over the years indicate the positive effect these awards have had on faculty recruitment and performance.

THE SCIENCE ALLIANCE TODAY

In July 1994, the Science Alliance marked ten years as the primary channel for promoting research and educational collaboration between UTK and ORNL. One UTK chemistry faculty member with a long record of ORNL collaborations likened the role of Science Alliance to that of "a lubricant." He credits the center with easing the assembly of "uniquely capable" UT/ORNL research teams, such as the one he is part of, which combines the capabilities of UTK's synthesis and mass spectrometry groups with ORNL's Health and Safety Research Division, Nuclear Magnetic Resonance group, and physics groups. Because of the global nature of scientific research and the increased productivity that occurs when interests are combined, Science Alliance Director, Dr. Thomas A. Callcott has expanded this focus to include resource sharing wherever possible. With these goals in mind, the UT/ORNL Science Alliance will continue its stewardship of valuable research resources.

Appendix D

Recent Facilities with Joint University - State - DOE Funding

a. Array of Compton-suppressed Ge detectors: $1.2 million:
Total cost, including $125,00 from Vanderbilt and
$320,000 from the University of Tennessee
(through the Science Alliance program);

b. Spin Spectrometer electronics upgrade: $40,000
contribution from the Science Alliance at UT; Total cost $100,000

c. Liquid helium refrigerator: $15,000 from Vanderbilt,
$75,000 from the UT Science Alliance; $40,000 UNISOR; Total cost $200,000

d. Electronics for neutron detectors: $40,00 from Vanderbilt
In addition, the detectors were built at Vanderbilt.

e. Compton polarimeter: $30,000 from Vanderbilt; Total cost $50,000

f. Recoil Mass Spectrometer: $500,00 from the State of Tennessee,
$155,000 from the UT Science Alliance, and $155,00 from Vanderbilt;
$250,000 UNISOR universities; $300,00 Martin Marietta - ORNL non
DOE funds, Total cost Spectrometer plus building $3,800,000

g. Radioactive beam facility development: $100,000 each from UT
and Vanderbilt.

h. 12 clover Ge detector arrays: $50,000 Vanderbilt, $50,000 UT,
$50,000 UNISOR Universities, State of Tennessee $150,000;
Total costs: $1,800,000

i. Focal plane detections for RMS: $55,000 UNISOR
$20,000 Vanderbilt, $170,000 English universities;
Total cost $250,000

Chairman STEVEN SCHIFF. Thank you very much, Dr. Hamilton. I want to take care of two technicalities: First, I introduced my own written statement into the record, but I want to ask the unanimous consent that if any members of the Congressional panel has an opening statement, that it also be allowed into the record. Without objection, so ordered.

And I'd also, if I didn't do it before, ask unanimous consent that the written statements of each of the witnesses be admitted into the record. Again, without objection, so ordered.

Well, since Congressman Zach Wamp is the organizer of this project, this Summit, and the reason why we're having the field hearing in Oak Ridge, I'd like to ask Congressman Wamp to begin the questions, please.

QUESTION AND ANSWER SESSION

Congressman ZACH WAMP. Thank you, Mr. Chairman. My first question is directed to Dr. Krebs and Dr. Lane. But as Dr. McTague referenced, I think it would be good for this new Congress, the new Congress would do well to remember President Reagan, remember kind of the godfather of the modern conservative movement. Because, as you touched on, Dr. McTague, President Reagan proposed doubling the budget of the National Science Foundation over a period of—I think five years. Dr. Lane, is that correct?

Dr. NEIL LANE. Correct.

Congressman ZACH WAMP. And that was actually accomplished. So as we look at downsizing Federal Government, reprioritizing our Federal investment and our limited resources, I think we need to remember those years, remember that president, remember his leadership.

If we actually had some areas of energy research increased in funding—now that sounds like something that wouldn't take place in this climate—but if we were to reprioritize our energy research funding, there's tremendous competition. I mean, now hydrogen, because of Chairman Walker's interest in hydrogen, is very much on the table. Fusion, fossil, neutron, wind—just on and on and on different energy research efforts that are competing for limited funding.

And I know you shouldn't really answer this question probably, but I'm going to ask it anyway and ask you to please try to answer this question: Where would you spend the money if you could increase funding in some energy research areas during this time of budget concerns? Dr. Lane and Dr. Krebs.

Dr. NEAL LANE. Start with you. [Parties laugh.]

Dr. MARTHA KREBS. Well, I think, in fact, the Secretary's and the President's budget in energy research has some selected increases. And certainly, within the basic research programs, the increases which I know best and can defend most strongly—so let me speak to those—are the increases for the science facilities initiative, which would impact in the twenty-six, twenty-seven user facilities that are spread throughout the laboratories, throughout the laboratory system, would affect hydrogen physics and nuclear physics facilities, it would affect facilities like the HFIR reactor, but also the

reactor, the neutron reactor at the Brookhaven National Laboratory, would affect operations at the synchrotron facilities.

And essentially, right now those facilities, through user facilities, service some fifteen thousand users—predominantly from universities. I was thinking, as Dr. Hamilton reflected on his career, he's just one of fifteen thousand users who probably have as interesting stories—certainly, I'm sure two-thirds of them do—as interesting stories as Dr. Hamilton.

And what we do know is that these facilities are over-subscribed by a factor of two or three. And the facilities initiative, we estimate, would allow us to provide access and new capability to at least three or four thousand more users. So, let me simply say that I know that, within my programs, that's a worthy candidate for increase.

Dr. NEAL LANE. Congressman Wamp, I think probably my most accurate answer to the question is in the context of how NSF approaches its work research activities, research and education activities. We don't specifically have program targeted for areas of application. We do, I think, have strategic areas of focus of research activities; one of these is the area of manufacturing technology, another is applied materials, another is high-performance computing communication.

Where we really try to place our emphasis is on areas of science and engineering research that not only are intellectually challenging and really do push the science frontier—that is our mission—but that also, when done in a critical frame of time—a window, if you like—bring knowledge together in a way that impact the generation of knowledge and technologies applicable to larger societal issues, such as energy and environment.

So, we invest substantially, have done so in recent years, in modern materials, in optical science and engineering—that's an emerging area—sustainable technologies, manufacturing. To make manufacturing process more benign, not just to protect the environment, as important as that is, but also to increase efficiency. That's an important aspect of energy consideration.

So, our approach is to support the best and the most fundamental important science and engineering at a given time, but also to pay special attention to those opportunities in time where we can bring together chemistry, physics, biology, areas of engineering, to develop the knowledge necessary to push these larger issues that are, indeed, areas of national need.

Chairman STEVEN SCHIFF. I wonder if the Congressman will yield for a moment?

Congressman ZACH WAMP. Yes, sir.

Chairman STEVEN SCHIFF. Congressman Wamp asked a question about if you had increases, where would you place it. Although I'm sure you could find places where it would be warranted, I'm sure you're aware that the chances of that happening in the current budget situation are, I think they say between slim and none. And I say that with utmost regret.

But I just wanted to emphasize a particular reason why the balanced budget must be a goal. And as I hope I indicated before, I think the responsibility for not having balanced in the past can be shared among presidents, Congress, both Republican and Demo-

crat. But I point no finger. By, you know, this fiscal year I think the interest on the national debt will be right around two hundred and thirty-five billion dollars. That is the third highest line item in Federal spending—of all Federal spending—next to Defense and Social Security.

Now, we pay interest on our debt in Government the same way anyone else pays it; it comes right off the top. Same way if you have a credit card debt or an installment loan.

The point I'm getting at is, the taxpayers of this country are paying enough money today, without a tax increase, to fund an increase in NSF, Department of Energy, and about any other project you can think of. But the problem is, we must take two hundred and thirty-five billion dollars of taxpayer-paid money and, from a productivity standpoint, throw it out the window. Because interest doesn't buy more guns, it doesn't buy more milk and butter.

And I'm just saying, that's a very, very practical reason, not a philosophical one, why we have to get this matter under control. Because the money is there, we just have developed a situation where we're misusing it. I yield back to the former.

Congressman ZACH WAMP. I yield back to you, Mr. Chairman, for the next round of questions.

Chairman STEVEN SCHIFF. I'm going to recognize, then, Congressman Hilleary. Again, we're in your state, you're now recognized.

Congressman VAN HILLEARY. Thank you, Mr. Chairman. I'd start out by I guess asking a poor working stiff there, Dr. Hamilton, and Dr. McTague, to comment on how the Federal Government, one, could do more than we're doing to integrate industry and universities to further our common goal, which is to maximize, I think, our science technology and our economic growth for the future. And what, if anything, should we be doing less of, or should we cease and desist what we are doing that hampers that further integration?

Dr. JOSEPH HAMILTON. Well, one thing I mentioned in my remarks is the following: I think the Federal Government needs to take more opportunities to strengthen the kinds of partnerships that have developed, say, in the State of Tennessee between the state government and its universities. And which the universities are really putting in hard money into the Oak Ridge National Laboratory.

Universities in the State have put in, over the last six years, more than two-and-a-half million dollars of capital equipment money. This is in addition to monies that we've put in on visitor's programs, a whole variety of things. If I totaled it up over the last ten years, it'd be more than six million dollars of hard State of Tennessee, Vanderbilt, University of Tennessee, Knoxville, money has gone into those programs.

Yet, at the same time, I don't think there has been as much that the Department of Energy has done, that they could have maximized even more those partnerships than what has been available. I think they need to encourage those so that they will encourage other states to take that same kind of initiative, in Illinois, in New Mexico, in California, et cetera, for their universities and states to think about putting in cooperative-project money.

And the only way to do that is to selectively kind of influence the direction that you're going with the money you have, if you want to encourage other people to do so.

Congressman VAN HILLEARY. And non-monetary things that——

Dr. JOSEPH HAMILTON. Well, it is terribly important—that this whole question about the Department of Energy—I cannot underscore how vital the Department of Energy's Laboratories are to university scientists around the country. If you abolish that, or even if you try breaking it up, and say, okay, we're going to abolish this, we'll farm this laboratory out, or something like that, I think that would just have absolutely disastrous consequences.

I would agree that there are ways in which we can scale, administratively and other things, to streamline the programs, and I would encourage that to be done. But I don't think that calls for an abolishment of the Department of Energy, and it certainly doesn't call for abolishment of the Laboratory facilities which have become so essential in a time of big science to so many university people and so many graduate students and even undergraduate students.

I would second your Chairman's remarks on that score, that that's a vital position we have to take.

Congressman VAN HILLEARY. Thank you.

Dr. JOHN MCTAGUE. From my many years of experience with the Department of Energy, all facets, it seems to me that the present climate offers a golden opportunity to make the National Laboratory system substantially more efficiently effective. And that is by reducing the level of central control in micromanagement. [Audience applauds.]

Dr. JOHN MCTAGUE. This level of micromanagement and overregulation from the center has resulted over the years, I think, from addressing specific problems. One specific problem coming from one particular place, possibly one action of one person generates a regulation to make sure that that never happens again. Nobody ever looks at what's the overall effect. And the increasing of these regulations over the years has very severely hampered the capability of local managements to make clever, cost-effective decisions.

Dr. Trivelpiece should be judged not by how he has conformed to seventy-seven different audit commands, but he should be judged by what's the output of the Laboratory. He should be given the capability to determine what the output of the Laboratory will be.

And if there's anything that I—if I were czar for the day—if there's anything I could do with the Department of Energy, I think it would be basically to prevent the Department from having the capability to do these things. And one way to do that is to arbitrarily eliminate half of the bureaucracy. Just eliminate 'em. [Audience applauds.]

Chairman STEVEN SCHIFF. I think, Congressman Hilleary, a couple of other panel members want to respond. [Parties laugh.] Somehow, I think Dr. Krebs is entitled to be first, though.

Dr. MARTHA KREBS. I couldn't agree more. [Audience applauds.]

But let me expand upon that, please. Clearly, this issue was something that drove the findings of the Galvin Report. It's what the Galvin Committee heard when they came out to the Labs,

when they went to the customers of the Laboratories, when they went to the users of the Laboratories, and when they talked to people in DOE as well. At least some of the people in DOE. And the Department has taken the recommendations of the Galvin Committee very seriously. I think it's a great challenge to the Department to deliver on the changes that it has begun to make. It has begun to look at its order system and pare it down, it has begun to look at the way it does audits and reviews in the field, in business issues, environmental health and safety, and even program reviews.

And so, it has begun to look at how it's going to administer and enable the Laboratories at the working level to determine what kinds of standards for environmental health and safety, if in fact, they are going to use in order to do their work. And so, I believe that we can put in place some approaches—to setting standards, to doing oversight and review—that could reduce the effort and the cost that has been put into the system.

I have to say, however, having observed the interaction between the agency and the Congress over the last fifteen to twenty years, some of the actions that the Department took, some of the rules that were put in place—perhaps as in an overreaction—but, nonetheless, what they did was often in response to a point of view and a kind of oversight that was taken in Congress. So this is something that we have to do together, it is not something that simply the agency can do, it is not something I believe that simply removing bureaucrats can do.

However, having said that, the Secretary, in her alignment—strategic alignment activity—is taking people out of the system. And I believe, I know, that within Energy Research, if we take people out of our system, we have to take work out of that. If we take work out for ourselves, then it also means we have to think about how we take work out for the Laboratories.

But this is something that we have to do together, it is not something that just the Department can do. Because what the Department did in putting the burdens on the Laboratories was something that was a response. And the Department, to be perfectly honest, like the Laboratories, are pretty responsive to their sponsors.

Chairman STEVEN SCHIEFF. Thank you, Dr. Krebs, for responding. Dr. Hamilton, did you want to add anything?

Dr. JOSEPH HAMILTON. I like giving concrete examples of things, and I give you two from the Joint Institute for Heavy Ion Research. Our second building is owned by the University of Tennessee. It was built three years after the first building. The first building, Vanderbilt and U.T. gave money to the Oak Ridge National Laboratory to build the first building. The second one, we rented the land from the Department of Energy and built the building through the State of Tennessee, and it's owned by the State of Tennessee.

Three years later—this is now in 1981 to '84, when inflation wasn't terribly low—we built a fifty-percent larger building for a hundred thousand dollars less because of the constraints—building constraints—that were put on for Oak Ridge National Laboratory to build the building.

Another example, recently we had to put a roof on the Joint Institute, and the University of Tennessee went out on bids like they

would've normally have gone through, because it was their building, came back with a bid of twenty-five thousand.

But then we discovered, nope, we had in our agreement signed that we would obey all the rules and regulations the Oak Ridge National Laboratory would obey. When the company was told that, we were told the roof would cost sixty-five thousand dollars. [Audience applauds.]

Chairman STEVEN SCHIFF. Congressman Hilleary, anything further?

Congressman VAN HILLEARY. Mr. Chairman, I have so many other questions, a couple especially, that, as you know, when we're in Washington, poor Zach and I are so far down in seniority that we often don't even get to ask any questions. (Parties laugh.)

I don't want to abuse this unique opportunity, although be it a temporary position. I'll save you from myself, so I'll yield back to you.

Chairman STEVEN SCHIFF. I do remember. It wasn't all that long ago. Congresswoman Lloyd.

Former Congresswoman MARILYN LLOYD. Thank you very much, Mr. Chairman. I do want to congratulate all the witnesses on their excellent testimony, and thanks to you, Mr. Chairman.

Dr. Lane, in your testimony you spoke very favorably toward greater interaction and enhancement of the work between the private sector, the Labs, the universities. I was wondering just how much research does the National Science Foundation fund at the National Laboratories, and are there restrictions for funding these facilities?

Dr. NEAL LANE. Congresswoman Lloyd, there are not mandated restrictions by Congress, there are policies of the NSF. And the policy is that NSF does not usually make grants directly to investigators in the National Laboratories, but we do, in fact, support many activities that take place in the Laboratories or elsewhere that involve Laboratory staff.

That's true when, to some extraordinary circumstance, where the science that can be done in the Laboratory is especially closely related to science we're supporting in universities. It's also the case when we have joint activities, such as the supercomputing, advanced parallel computing activities involved at Los Alamos—a similar project here—are projects where many institutions are involved, some universities we support and some National Laboratories.

So, there are a number of examples where NSF funds are used on research that involve personnel of the Laboratories. But in the past, our policy has always been not to, in a sense, put NSF money in place of the money of a mission agency or when we have an obligation, in fact, to ensure that research and education are done in an integrated environment. And that causes us to invest most of our money in the universities.

Probably the amount of direct grants is quite small, on the order of a couple of million dollars, but when you include these other ancillary activities, it's much larger than that. I don't know the exact amount.

Former Congresswoman MARILYN LLOYD. I'd like to ask you Dr. Lane, and the other witnesses as well, to briefly comment on this:

do you believe there's a difference in the quality of the research performed by the National Laboratories that's funded by DOE and the research that's funded by NSF? In the quality of work.

Dr. NEAL LANE. Could I start with that one and then ask my colleagues to join? I don't have any data, comparative data, of any kind, I'm not aware of studies that have made to compare the following, so all I really know is anecdotes.

My personal experience involves years of interaction primarily with Los Alamos and Livermore, collaborations with scientists there, but of course there were, and still are, a number of colleagues at this Laboratory. There is no difference, in my view, in the quality of scientists and the work that is done and is published by these individuals in comparison with those at universities.

Dr. MARTHA KREBS. Again, I can't compare scientists supported by DOE with scientists supported by the National Science Foundation. However, what I do know is that we have looked at—within the Office of Energy Research—we have looked at, by peer review, the character of research supported at National Laboratories and the character of and quality of research supported by DOE at the universities.

And since we use a peer review process, both in terms of selection and in terms of the subsequent performance, we don't detect a substantial difference between our university performers and our National Laboratory performers. So that says that at least uniformly within the Department of Energy, we are investing in a comparable quality of work at both universities and National Laboratories.

Former Congresswoman MARILYN LLOYD. Dr. McTague, do you agree?

Dr. JOHN MCTAGUE. I think if there is a difference, the difference is more not so much in terms of quality——

Former Congresswoman MARILYN LLOYD. I was referring to quality

Dr. JOHN MCTAGUE. It's more a level of focus and the encouragement of team work that occurs at the Laboratories, because so much of the research is focused around unique facilities. Having scientists that are dedicated to doing research locally to keep these facilities up to par and make sure that they're the best in the world, and to encourage outside users, is a service that also occurs while the research is being produced.

So, the criteria for judgment of quality should take into account what the goal of the research is. So there is a different way of judging quality, it seems to me, for research at the National Laboratories than there is in universities. But that being said, I think when you take into account the full measures of quality, I agree with Dr. Krebs and Dr. Lane.

Former Congresswoman MARILYN LLOYD. Dr. Trivelpiece.

Dr. ALVIN TRIVELPIECE. I would certainly agree with what my predecessors have said here. I would add only perhaps a different approach to this. Dr. Galmon, a famous professor, Nobel Prize winner from Cal Tech, has been concerned in the past few years and has dedicated some effort toward trying to persuade academic institutions that one of their weaknesses is, in fact, that they have narrowly-defined disciplinary structures to their academic format.

And that one of the strengths of National Laboratories is the fact that interdisciplinary work is extremely easy. It's more difficult in academic settings, easier in a National Laboratory setting. So the kinds of things that we can routinely put together, from my own experience as a Physics professor, turned out to be fairly difficult in an academic setting.

Former Congresswoman MARILYN LLOYD. Dr. Hamilton.

Dr. JOSEPH HAMILTON. From the standpoint of quality, I would have to say that I don't know of any working scientists who believe there's a difference in quality. I guess I would say that, since I've spent forty percent of my career funded by NSF and the other sixty percent of my career funded by DOE——

Former Congresswoman MARILYN LLOYD. You're pretty well balanced. [Parties laugh.]

Dr. JOSEPH HAMILTON. That's some degree of balance on that score, and I have an indebtedness, therefore, to both of them. I would agree with what Dr. Trivelpiece has said, universities are a little more difficult to develop into disciplinary programs.

On the other hand, the university scientists have a greater freedom in some ways to pick and choose the directions that they want to go, and they can pick and choose the National Laboratories, if they want to go into them. And if they want solely to change direction, it's a little easier for them to do that. But I don't see that that affects the quality.

I do want to underscore, however, that one of the tremendous strengths of the U.S. Science Program has been with dual funding of science through the NSF and the Department of Energy. It's a unique thing in the world. And one of the reasons that we have one of the preeminent science programs in the world is the fact that we have that dual track of funding. And if you want to kill science in this country, one way to do it is to kill that dual tract.

Former Congresswoman MARILYN LLOYD. Thank you very much. Dr. Krebs, I'd like to talk about spallation neutron source. As you know, I lived through trying to keep the SNS supported for many, many years and I'm very concerned about this program. And certainly the Oak Ridge community wants to see the design, the construction, and operation of this neutron source.

But given the outcome of SNS, what would you recommend to this community, to Congressman Long and to the Senators who really work to hold onto this program? Do you see that it's likely that you'll be able to seek funding as a line item for the SNS? And as you know, priorities are sometimes rearranged.

Chairman STEVEN SCHIFF. I have to intervene at this point and ask you for a brief answer, Dr. Krebs, if you would, please.

Dr. MARTHA KREBS. A brief answer. The brief answer is, we put it in the 1996 budget, not upon line item but we put it at the beginning of the 1996 budget. We were prepared to re-program in the 1995 funding. My sense of not living through the whole thing, but living through the first three years, was that we didn't have consensus from the Congress to support a two-and-a-half- to three-million-dollar facility.

I think I have to ask the question back, is there going to be a consensus in the Congress for a, you know, around one-billion-dol-

lar facility for science? The Administration is waiting to find out. We started it.

Former Congresswoman MARILYN LLOYD. Thank you. I yield back, Mr. Chairman.

Chairman STEVEN SCHIFF. Thank you, Congresswoman Lloyd. For the closing question, let me turn back to Congressman Wamp.

Congressman ZACH WAMP. Thank you, Mr. Chairman, once again for being here, and everyone for participating.

The superconducting supercollider is perhaps the best example of a long ball, as I think the Gipper called it at one time. Throwing the ball deep, making that big investment, long-term scientific investment in this country. And as we all know, budget constraints caused the termination of that multi-billion dollar science project.

We elect a President every four years. It seems to be very difficult to be reelected President of the United States. We elect Senators every six years, House Members every two years. Political winds come and go, budget constraints are constantly upon us, into the future, now.

What can we do to set a long-term science strategy, stick to it? Is it a commission? I mean, we appoint Federal judges for life; if we did to the Federal Courts what we do to science planning and investment in this country, they would even be more chaotic. What can we do? What can we do to lend some continuity to this process so that we're not constantly making an investment and then bailing out on it and wasting dollars? Dr. Trivelpiece.

Dr. ALVIN TRIVELPIECE. I think the simple strategy is to try to fund some of these major science projects in the same way that the military funds battleships; that is, you authorize and appropriate the money up front. You make the decision to do so.

The Department of Energy has a lot of projects; suppose it put all of its money on one project one year, then debated on what it was going to do next year, put whatever money it had that year for the next project. Then those projects would have some stability and continuity.

It's a pretty radical approach to dealing with funding of science projects, but at least it's one mechanism by which you might put a little bit of stability into the system so it couldn't be uprooted quite so easily.

Chairman STEVEN SCHIFF. Anyone else want to give a brief response to the same question?

Dr. MARTHA KREBS. That's a good response.

Dr. NEAL LANE. We agree. I would only add to that that now, probably more than ever, it's going to be absolutely essential that a science policy ought to be able to garner strong bipartisan support, be the one that wins the day. We go forward on that one, rather than one that squeaks by in one year or other by a number of tradeoffs. That, perhaps, has been the case on other projects in the past.

It seems to me the old way doesn't work anymore, so we just have to work together very hard to build a strong bipartisan consensus for our policy.

Chairman STEVEN SCHIFF. Well, we've reached the point where we're at a time constraint because of the next program that's already planned for this time. May I presume that the five witnesses

here would be receptive to answer in writing any questions that might be submitted in writing for the record here?

I'm going to ask unanimous consent that the record remain open for fifteen days for the purpose of asking and answering in writing any questions, if there are any further. I appreciate that on the part of the panel. So ordered.

With that, it's time to say that this was a very constructive hearing——

Congressman ZACH WAMP. Would the Chairman yield for an announcement?

Chairman STEVEN SCHIFF. I can.

Congressman ZACH WAMP. At four-thirty, the Chairman and I will be demonstrating, through robotics, a process link between Sandia and Oak Ridge, where we will actually be operating a robot in Sandia from Oak Ridge at the Garden Plaza at four-thirty. And I would ask that Congresswoman Lloyd and Congressman Hilleary try to join us there, and anyone else that's interested, and that'll put you right in the thick of the next presentation. Thank you, Mr. Chairman. Yield back.

Chairman STEVEN SCHIFF. I just want to say I hope everyone who attended appreciated the testimony of the witnesses as much as we did here. And I want to thank the panel and my colleagues, and declare the hearing adjourned. [Audience applauds.]

[Whereupon, these proceedings were concluded, and this hearing was adjourned.]

APPENDIX

Questions for the Record for Dr. Neal Lane, NSF, From Representative Schiff, Subcommittee on Basic Research

#1

QUESTION: With the end of the Cold War, some have proposed that national science and technology policy be oriented towards: international economic competition; civilian technology development; a shorter term return on results and a more strategic focus; interdisciplinary and interagency program orientation; and a team/center/consortia focus in the conduct of research and development. Please comment on these proposed new policy directions.

ANSWER: The basic research supported by NSF underpins advances in both the civilian and defense sectors of the economy, leading to increased long-term economic competitiveness. Within this framework, basic research has served, and will continue to serve, national interests.

Strategically focused research and basic research are not mutually exclusive. NSF support is almost entirely for basic research. Yet, the preponderance of the research supported by the Foundation is in areas of clear importance to the nation. Excellent research within a strategic focus is no different from the basic research that produces many of our scientific breakthroughs.

NSF is unique among Federal agencies in having responsibility for the overall health of science and engineering across all scientific and engineering disciplines. Thus the balance we must strive for is between research in areas of obvious importance to the nation, and a broad base of research activities in other areas of science, to maintain the vitality of science for unanticipated breakthroughs, where payoff timeframes are often unpredictable.

NSF supports the partnership approach to the conduct of research, including such activities as interagency and interdisciplinary programs. Partnerships and people are the key to knowledge transfer. In order to deliver the greatest return on its investment in creating new knowledge and developing intellectual capital, NSF is continuing to take leadership in fostering and catalyzing partnerships with industry, academe, and other communities.

#2
QUESTION: With the Administration and the Congress projecting decreasing Federal budget support for research and development over the next five to seven years, how must the relationships between the Federal laboratories, the research universities, and industry evolve to assure adequate science and technology investment for the nation's future?

ANSWER: Over the next few years, the increasing constraints on federal support for research and development (R&D) will increase the importance of coordination and cooperation between all the parties involved in the nation's R&D infrastructure -- federal agencies, academe, state and local governments, federal labs and industry.

One key for maximizing the impact of Federal funding for R&D is through expanded partnerships and collaboration. By leveraging Federal funds with contributions from other sources, some of the effects of reduced R&D investments can be mitigated. Partnerships and collaborations enhance the quality of the research that is conducted, increasing its usefulness to all involved, foster the essential knowledge transfer between the different sectors, and better prepare students for careers in industry and government. Such cooperation brings many disciplines and backgrounds together to solve complex problems, and can increase the potential for early application of the knowledge generated. In a changing and challenging environment, these partnerships will continue to develop and evolve.

The importance of industry participation in federally supported research programs cannot be overstated. Industry involvement reduces costs to the taxpayer, promotes technology transfer to the private sector, and helps make federal research more relevant to industry needs and U.S. competitiveness.

A second key element to meeting these coming challenges is the increased need for prioritization in R&D activities. Federal agencies must set rigorous priorities based on realistic budgetary expectations. For NSF, this requires determining which activities should be started, sustained, or phased out within overall R&D environments, and communicating these priorities to the broader community. And this must be done in the context of the NSF Organic Act, ensuring a balanced, healthy science and engineering research enterprise.

#3
QUESTION: Would integration of all Federal science and technology agencies into a single, cabinet-level department contribute to more efficient support for research and development?

ANSWER: Any large-scale consolidation of all Federal science and technology agencies could have significant ramifications for the future competitiveness and economic health of the United States. We at NSF urge caution when structural changes to the federal R&D system are considered.

The National Science Foundation is responsible for supporting fundamental science across all scientific disciplines, the only federal agency with such a broad responsibility. NSF strongly believes mission agencies such as the Department of Energy (DoE) and the Department of Defense (DoD) must also continue to support fundamental research. These agencies are integral parts of a complex and highly pluralistic system of support for research that evolved after the Second World War. In this tightly interconnected arrangement, industry, government agencies and academia each perform complementary roles. Within the federal government, agencies possess unique research and management capabilities critical to their assigned mission. This system remains the finest in the world.

Several key factors should be weighed before considering changes to the federal support structure for R&D. These include: the degree of overlap between ongoing federal R&D programs; the balance between consolidation and the benefits flowing from the variety of objectives, approaches and cultures inherent in the current system; and the flexibility provided by the current system. Also, questions of accountability must be answered. Specifically, would consolidation facilitate greater accountability? Would certain areas of research get less scrutiny?

Changes in the federal R&D complex may be necessary as Congress and the Administration look for ways to reduce the deficit. At the same time, it is critical that we at least preserve--and even enhance--the strength of the current R&D system. In particular, any new alignment must foster coordination and cooperation among complementary federal R&D functions.

NSF is working closely with the other R&D agencies to support research in a more efficient and effective manner under the leadership of the National Science and Technology Council. NSF is also participating in the second phase of Vice President Gore's Reinventing Government Initiative, to achieve cost savings within the existing agency structure. Through these interagency initiatives, we are striving to preserve the many positive features and assets of the current federal R&D system while improving our effectiveness and reducing costs to the American taxpayer.

#4

QUESTION: What is the appropriate role of the National Science Foundation and the research universities in research and development in the energy and environmental sciences? How is this best integrated with DoE-supported research?

ANSWER: The National Science Foundation is responsible for supporting fundamental science across all scientific disciplines, primarily through support for research at U.S. academic institutions. NSF is the only federal agency with such a broad responsibility. NSF is working closely with the other R&D agencies, including the Department of Energy (DoE), to support research in a more efficient and effective manner under the leadership of the National Science and Technology Council.

For example, areas of cooperation include coordination of environmental research through the NSTC Committee on Environment and Natural Resources. In addition, senior management of NSF and DoE recently met to discuss collaboratory activities in basic energy sciences. The two agencies have a long history of cooperation and coordination in these areas.

QUESTIONS FROM REPRESENTATIVE SCHIFF FOR DR. MARTHA KREBS

Q1: With the end of the Cold War, some have proposed that national science and technology policy be oriented towards: international economic competition; civilian technology development; a shorter term return on results and a more strategic focus; interdisciplinary and interagency program orientation; and a team/center/consortia focus in the conduct of research and development. Please comment on these proposed new policy directions.

A1: During the past 50 years, the nation has had a stable, long-term science policy based on the strategy provided in the landmark 1945 report by Vannevar Bush to President Truman--Science the Endless Frontier. That report has been the foundation of our scientific past, but it is not likely to govern the future. Federal R&D spending patterns are going to change. That will require that the nation address the range of issues raised by the committee. In the meantime, the science and technology mission in the Department of Energy is to support the other core missions of the Department: protecting our national security and reducing the nuclear danger; weapons site cleanup and environmental management; and enhancing the Nation's energy security by fostering an economically and environmentally sustainable future.

National policy for science and technology should, I believe, emphasize Federal investment in long-term research and development that addresses agreed upon national missions including the generation of new knowledge and the preparation of the next generation of scientists and engineers. This investment will rely on partnerships between disciplines, agencies, industries, and nations. Only within this broader scope can we gain the most from overall and world-wide progress in addressing common problems.

We will also strive to use results from science and technology to stimulate U.S. industrial technology development so as to increase our international economic competitiveness.

QUESTIONS FROM REPRESENTATIVE SCHIFF

Q2: With the Administration and the Congress projecting decreasing Federal budget support for research and development over the next five to seven years, how must the relationships between the Federal laboratories, the research universities, and industry evolve to assure adequate science and technology investment for the nation's future?

A2: Federal laboratories, universities, and industry each have an essential role in the overall U.S. scientific and technological capability. University research is often innovative and creative, leading sometimes to truly breakthrough technology. Federal laboratories are a major source of multi-disciplinary, team-oriented, long-term research and development focussed on major national problems. The Department of Energy invests in large, unique research facilities at the DOE laboratories, and these user facilities are an important contribution of the Department to the physical infrastructure of the American science investment. More than 15,000 users depend on the operation of these facilities to advance science. The users are predominantly from the Nation's universities and are most often funded by other agencies. Industry is the force that takes new and improved technologies into the marketplace with new and better products and services. The roles of the universities, the national laboratories, the user facilities, and industry are truly synergistic and complementary and do not need to change in any fundamental way.

The relationship between these entities may change, however, with decreasing budgets, though there is no way at this time to predict how it will evolve in any detail. It is likely that partnerships will become a more common feature of research and development, as each entity

strives to use contributions of the others. It is possible that Federal laboratories will take on a larger share of the Nation's long-term technology research and development as industry moves even further toward short-term research and development for product and process improvements. User facilities will probably become more important as scientists and engineers from universities and industry increasingly move to take advantage of the unique capabilities of these centralized facilities; capabilities that they cannot duplicate in their home institutions. Trends at universities that will probably increase are to tie research work into the education of students and to train science and engineering graduate students more broadly so that they can work more productively in businesses and industry.

QUESTIONS FROM REPRESENTATIVE SCHIFF

Q3: Would integration of all Federal science and technology agencies into a single, cabinet-level department contribute to more efficient support for research and development?

A3: The proposal to create a Department of Science to receive parts if not all of the Department of Energy -- as well as NASA, the National Science Foundation, the Environmental Protection Agency, and parts of the Departments of Commerce and Interior -- does not seem workable or advisable. The result would be a monolithic new bureaucracy with a budget perhaps exceeding $46 billion, more than 77,000 federal employees, and more than 300,000 contractor employees. Past and present science advisors to the President have expressed their opposition to creation of a Department of Science. Joining our Presidents is the scientific community that sees the establishment of a Department of Science as a risky action that could threaten the Nation's leadership position in science. In their view, based on fifty years of prior consideration, and in ours, such a department would involve more bureaucracy, not less, and would sacrifice the diversity of funding resources and research avenues that have made this Nation's scientific establishment the envy of the world.

QUESTIONS FROM REPRESENTATIVE SCHIFF

Q4: What are the DOE and national laboratories doing to establish clear mission statements for the labs which can be utilized for future budget decisions and long-term strategic planning?

A4: Under the leadership of Robert Galvin, Chairman of the Executive Board of Motorola, Inc., the Task Force on Alternative Futures for the DOE Laboratories produced a landmark assessment of the laboratories. The DOE is now aggressively implementing the report's recommendations. One of the recommendations of the Task Force is that the DOE and the national laboratories should promptly establish clear mission statements for the laboratories which will be utilized as tools for budget decisions and long-term strategic planning. A Laboratory Operations Board has been established by DOE in response to the Task Force recommendations. One of the objectives of the Laboratory Operations Board is to ensure that the recommendations are realized, including developing clear and concise laboratory mission statements which would define and clarify strengths among the laboratories as a framework for future budgetary and strategic planning decisions. The Laboratory Operations Board held their first meeting on June 29, 1995. The members agreed the Board should be involved in developing focused laboratory missions and a mission statement for the DOE laboratory complex.

QUESTIONS FROM REPRESENTATIVE SCHIFF

Q5: What is the DOE doing to establish lead labs and Centers of Excellence within the lab system?

A5: Another recommendation of the Galvin Task Force on Alternative Futures for the DOE National Laboratories is the establishment of lead laboratories and Centers of Excellence within the laboratory system. This recommendation will also come under the purview of the Laboratory Operations Board which will propose whether the DOE should designate lead labs and Centers of Excellence within the laboratory system to facilitate more responsible management, better business practices and retention of specialized scientific leadership while encouraging broad multidisciplinary scientific capabilities. As previously stated the Laboratory Operations Board held their first meeting on June 29, 1995.

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QUESTIONS FROM REPRESENTATIVE SCHIFF

Q6: What further, if anything, should the Federal government be doing in the area of technology transfer from the national labs?

A6: The federal government should support the federal research portion of cost-shared joint research activities between private industry and the national laboratories which meet the criteria identified for such collaborations in the Galvin Task Force report. The criteria are that the economic impact of R&D performed grows from the laboratories' core missions and that the collaborations supported provide benefit to the laboratories' core missions, are cost-shared, and are industry driven.

The Office of Energy Research program in place that performs this mission is the Energy Research Laboratory Technology Transfer Program (ER-LTT), which supports maturation of promising basic research to the point where its commercial potential can be evaluated and developed by industry. The ER-LTT Program is a vital mechanism for applying the results of basic science research at the national laboratories to economic competitiveness. Project approval is contingent upon the project's benefit back to the public mission and basic science programs of the Department and the ability to strengthen laboratory core competencies.

The ER-LTT program offers the opportunity to individual companies, particularly small businesses, and to whole industry sectors, to team with the Department for generic, pre-competitive research. The industrial partner has the follow-on responsibility to carry out commercialization and competitive development of resultant technologies

QUESTIONS FROM ZACH WAMP

SUBCOMMITTEE ON BASIC RESEARCH

OAK RIDGE FIELD HEARING

JUNE 1, 1995

Questions for the witnesses:

- Our nation's budget crisis means that federal spending will have to be reduced. That being the case, what areas of research would you place more emphasis on and what areas would you place less emphasis on?

- What specific recommendations from the Galvin Task Force do you think should be implemented to improve the ability of the labs to conduct research?

- As you know, the House and Senate budget resolutions only provide examples of how to achieve a balanced federal budget by the year 2002. In your view, what should be done to ensure that our nation continues its commitment to a viable long-term science strategy?

- Much has been made recently about the role of the federal government in basic research and the need for it to get out of applied research. Can that be accomplished? Or, are the two so inextricably linked that attempting to do so would do much harm to our nation's long term science strategy?

- The emphasis of this field hearing is "A long term science strategy for the nation". With the way the federal bureaucracy adds sometimes hundreds of millions of dollars to the cost of R&D projects (i.e. the Superconducting Super Collider), how can we convince the American public that funding long-term science initiatives are necessary for our nation to remain strong and competitive?

TESTIMONY to COMMITTEE on SCIENCE

U.S. HOUSE OF REPRESENTATIVES

UNIQUE STATE - UNIVERSITY -
NATIONAL LABORATORY PARTNERSHIPS

JUNE 1, 1995, OAK RIDGE, TN

Joseph H. Hamilton
Landon C. Garland Distinguished Professor of Physics, Vanderbilt University
Director Joint Institute for Heavy Ion Research, Oak Ridge

UNIQUE STATE - UNIVERSITY - NATIONAL LABORATORY PARTNERSHIPS

The State of Tennessee, Vanderbilt University, the University of Tennessee Knoxville, and Oak Ridge National Laboratory in 1970 initiated the first of several unique partnerships that have had major impacts on research and graduate education in the State of Tennessee, the Southeast region, across the U.S. and internationally. These partnerships provide models of how to effectively marshall limited financial resources and share scientific talents and ingenuity to create world-class research facilities for use by university faculty and graduate students and national laboratory scientists. These partnerships have involved not just the sharing of financial resources but equally as important the sharing of scientific insights and efforts by university and laboratory scientists to build major new research facilities at a national laboratory. It is important to our nation that these be full partnerships and not just national laboratories opening their doors to universities. In this way we will maximize collectively the strengths in our universities and national laboratories. Such cooperative efforts between our universities and the Department of Energy's National Laboratories are critical to the continued health and strength of our nation's research in basic nuclear science and in the training of scientists who are essential for a broad spectrum of basic and applied fields from nuclear and diagnostic medicine, environmental safety and restoration, nuclear energy to basic research. While nuclear research is emphasized, our National Laboratories have many other unique facilities which also significantly extend and complement research in many areas of physics, chemistry, biology, engineering and computer science. For example, one has at ORNL the Materials Characterization and High Temperature laboratories which are used by university scientists. Such full partnerships between national laboratories and universities must be rewarded through additional federal support in order to encourage the development of such full partnerships in other national laboratories.

The first partnership with ORNL was the UNISOR Consortium which began in 1971. At that time there were no user groups in nuclear physics at national laboratories which had their own scientists carrying out research. However, budgets were becoming tight and big expensive accelerators were needed to carry out forefront nuclear research. Since only a few such accelerators existed and fewer would be built in the future, many on-campus university nuclear programs would stop. This would be a serious blow to graduate education of nuclear scientists. Thus Vanderbilt initiated a proposal for the State of Tennessee to join with Vanderbilt University, the University of Tennessee, nine other primarily Southeastern universities and Oak Ridge Associated Universities to initiate a new research facility at Oak Ridge National Laboratory mainly for use by university scientists. The State of Tennessee, universities, and ORAU provided 100% of the cost of the first isotope separator on-line to an accelerator in the U.S. They also pledged to provide 40% of the operating funds for the facility for five years. The acronym UNISOR stands for UNiversity Isotope Separator at Oak Ridge. Oak Ridge Associated Universities continued as an important partner in UNISOR, including being the fiscal agent for the operating funds for the facility. The universities in partnership with the State of Tennessee and the ORNL have continued to add new equipment in the $100,000 to $300,000 range, such as a laser facility and low temperature nuclear orientation facility to open up new research opportunities. Another major initiative of UNISOR was to bring from Europe a theoretical physicist in nuclear structure research to help guide and interpret the results of the UNISOR research program. This was the initial step that led to a national center for theoretical nuclear structure research at ORNL.

In 1991 on the twentieth anniversary of the founding of UNISOR and the tenth anniversary of the Joint Institute for Heavy Ion Research, an International Symposium on

Reflections and Directions in Low Energy Heavy Ion Physics was held in Oak Ridge. Appendix A gives an overview of the work of the UNISOR Consortium which now includes universities in Texas, Oregon and Maryland, and Oxford University (England) as well as nine universities from the States of Tennessee, Georgia, Kentucky, Louisiana, Mississippi, and South Carolina. Of particular importance, the UNISOR Consortium pioneered the opening up of Oak Ridge National Laboratory for use by university faculty and graduate students.

In the late 1970's when the new Holifield Heavy Ion Research Facility (HHIRF) with a new 25 million volt heavy-ion accelerator (still the world's largest) was being built at ORNL, Vanderbilt and The University of Tennessee Knoxville moved their partnerships with the State of Tennessee and ORNL to a new level with the development of the Joint Institute for Heavy Ion Research which is described in more detail in Appendix B, taken from the 1991 conference. Quoting from Appendix B, "The Joint Institute for Heavy Ion Research (JIHIR) is a unique institution in the world of nuclear physics. Conceived at Vanderbilt University in 1975, it is the result of a joint effort of Oak Ridge National Laboratory (ORNL), the University of Tennessee (UT), and Vanderbilt University (VU) to build a special university-like visitor environment at a national laboratory. In the process, the success of the JIHIR has occurred because of a new type of relationship between universities and a national laboratory, and a special collaboration between the federal government and the State of Tennessee."

The new Holifield facility was initiated with a major change in direction for Department of Energy National Laboratories in nuclear physics - a facility located at a national laboratory but used by scientists from around the nation and the world, and not a national facility used by in-house scientists. The Joint Institute was conceived to help make Holifield a nationally used facility. It is operated by the University of Tennessee, Vanderbilt University and Oak Ridge National Laboratory. Beginning with $100,000 pledges each from Vanderbilt and the University of Tennessee, ORNL provided the remaining funds for the first Joint Institute building. Funds for the second building were $44,000 from UNISOR and $350,000 from the State of Tennessee, along with additional funds from VU and UT. The institute buildings now are valued at over one million dollars. These buildings provide on-site lodging, office space, computer terminal rooms, and secretarial support for outside visitors along with a conference center.

Shortly after the first Joint Institute building was completed, and the second building was in progress, Vanderbilt and the University of Tennessee approached then Governor Lamar Alexander about having the State of Tennessee provide annual operating funds for a visitors' program to complete our Institute in the fullest sense of the word. We stressed that with such funds our Joint Institute would become a center of excellence in higher education like the State of Tennessee had not had before, attracting renowned scholars to Tennessee from around the world. A year later Governor Alexander introduced his Centers of Excellence program in higher education. The largest such center is the Science Alliance between the University of Tennessee Knoxville and ORNL as discussed in Appendix C and described briefly below. As part of the Center of Excellence grant to the University of Tennessee, the Joint Institute receives annually $165,000 to go with $30,000 from the Physics Division of ORNL, $30,000 from the Department of Energy and $12,000 from Vanderbilt University.

In general, $150,000 to $200,000 has been spent without overhead in our Joint Institute visitors program. The Joint Institute was a major factor in making HHIRF by far more used by outside scientists than any other DOE nuclear laboratory. During its last 10 years of full-time operation before shutdown to build the RIB facility, 640 scientists from 148 institutions including

200 graduate students and 38 undergraduates worked at HHRIF. In 1990 there were 59 graduate students who used Holifield for part or all of their Ph.D. work, a number five to ten times larger than at the other DOE national laboratory nuclear facilities. These visitors have had major impacts on the quality and quantity of research carried out by University and ORNL scientists at HHIRF. Of particular note, the Joint Institute made it possible to bring in world experts to help develop and make operational new pieces of equipment. Of special note, Holifield is now being rebuilt as the first US radioactive ion beam (RIB) facility. Most of the world experts in this area are in Europe. Over the last two years the Joint Institute has brought distinguished scientists from several European countries and from other U.S. laboratories to provide critical help to develop this new RIB facility.

Three other major efforts of the Joint Institute are: a) the hosting of international workshops and conferences, b) obtaining State and university funds to match DOE funds for new facilities, and c) helping develop the first nuclear structure theory center in the U.S. For example, to date over 35 conferences have been hosted at the Joint Institute Conference Center with over 2,000 scientists at these meetings. The Joint Institute initiated steps which led to DOE's joining to create a center for Nuclear Structure Theory in cooperation with ORNL, the University of Tennessee and the Joint Institute.

The partnership of Vanderbilt, the University of Tennessee, the State of Tennessee, UNISOR universities, Oak Ridge Associated Universities and ORNL - DOE has provided the opportunity for them to cooperate in the sharing of funds to build specific new facilities at Holifield. For example, a major new facility, a new generation recoil mass spectrometer (RMS) was conceived at Vanderbilt which raised $1,500,000 toward the $2,2000,000 cost from university and external sources. It was designed by scientists at Vanderbilt, Texas A&M and Idaho National Engineering Laboratory. This $4,000,000 facility will be the centerpiece for research with the new ORNL RIB facilities.

The new RMS and RIB combined are a premier research facility, unmatched anywhere in the world. In the last six years university, the State of Tennessee, and ORAU funds for capital equipment at ORNL have totaled over $2,000,000 overhead free. A list of major contributions is attached in Appendix D. In addition, through the UNISOR Consortium several hundreds of thousands of dollars have been provided by the universities in purchasing small items of equipment, and in providing free shop work to fabricate components such as ion sources for use at ORNL. UNISOR has provided over $1,500,000 of overhead free direct support for the operation of the facility. ORAU has helped on several occasions by providing postdoctoral and graduate student fellowships for scientists to work at UNISOR. The State of Tennessee and Vanderbilt have provided over $2,000,000 over the last 11 years to operate the Joint Institute. The total of all university and state funds exceeds $6,000,000 (overhead-free) for the operation and development of the Holifield research program. In addition, even larger sums of money in a variety of science and engineering areas have been provided for targeted cooperative research between the University of Tennessee and ORNL through the Science Alliance, see Appendix C. But more important than money has been the enormous contribution in time and talents of university scientists both at home and in Oak Ridge to the development of the ORNL facilities and to the research there. Such true partnerships must be strengthened by rewarding laboratories and universities engaged with such partnerships with additional support if one is to encourage other such partnerships.

The tremendous success of the Joint Institute played a crucial role recently in the State of Tennessee's agreeing to provide $6,000,000 for a similar institute to support a proposed new neutron science facility if constructed at ORNL. Thus from modest beginnings of the State of Tennessee providing $90,000 in 1971 to match university contributions for the UNISOR project, the partnerships have matured and spread out to encompass support for a wide range of major research equipment and infrastructure facilities for scientists around the world.

Another outgrowth of the Joint Institute is the development of a Center for Computationally Intensive Physics. A cooperative proposal that includes funds from Vanderbilt, the University of Tennessee and ORNL won one of the Grand Challenge Awards in High Performance Computing to develop at ORNL one of the nation's major new high performance computer centers. This center is allowing university and laboratory scientists to address problems which are so complex and computer intensive that they could not be carried out with previous computer facilities. This cooperation has led to international conferences and new programs at Vanderbilt and UT in computational physics. Again, the success of one partnership opened opportunities to develop other new partnerships and important programs.

In 1984, as part of Governor Alexander's Centers of Excellence Program, a specific partnership, the Science Alliance between the University of Tennessee Knoxville and ORNL, was formed to promote scientific research and educational collaboration between UTK and ORNL. See Appendix C. Major features are the Distinguished Scientists and Collaborating Scientists Program with joint appointments involving shared costs. This is a broad-based program that includes many areas of physics, chemistry, engineering, biology and computer science. There are also funds for shared undergraduate and graduate programs and start-up funds for new projects. In addition to the major specific cooperative research efforts tied to the joint appointments, the Science Alliance also supports broad partnership ventures. The Joint Institute for Heavy Ion Research and many of the special research facility projects are supported through the Science Alliance. This program is an outstanding example of a specific partnership between a university and a national laboratory and of broad partnerships of national scope.

Finally, I would like to emphasize the importance of university-national laboratory partnerships to graduate education and research through a specific example. Over the last 35 years my research group at Vanderbilt has trained 70 postdoctoral fellows and over 50 Ph.D. students in experimental nuclear physics almost all of whom used the facilities at Oak Ridge National Laboratory for part or all of their training and Ph.D. thesis research. These scientists hold a wide range of positions in industry, hospitals, government agencies, national laboratories, colleges and universities. Our research, published in over 590 papers, has significantly advanced our understanding of the nucleus of the atom. Our specific example documents that our national laboratories are providing essential nuclear facilities for research of university faculty and graduate students in nuclear physics.

The partnerships between our universities, the State of Tennessee, Oak Ridge Associated Universities, and the Federal Government have been established to help provide world class research facilities for Tennessee university and ORNL scientists as well as scientists nationally and internationally. Keeping and expanding such partnerships are essential to the health and strength of many of our nation's university programs which are training the future scientists and technical personnel our nation must have to ensure its economic strength.

From: Proceedings of The Symposium on "Reflections And Directions In Low Energy Heavy Ion Physics" Edited by J.H. Hamilton, H.K. Carter, L.L.Riedinger and R.L. Robinson (World Scientific)

Appendix A

UNISOR

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Discussion

UNISOR is more than a facility, it is a collaboration with a remarkable spirit that came into being more than 20 years ago. While it continues to be the focal point for the nuclear structure research of many of its original members, the consortium has also attracted new participants who have helped sustain its collaborative spirit while, at the same time, contributing new ideas and expertise. The resources of the member institutions, both material and intellectual, have led to a number of major initiatives which have kept UNISOR research at the forefront of the study of nuclei far from stability. This process continues to this day through plans for research with a state-of-the-art recoil mass spectrometer and, most recently, through plans for research using radioactive ion beams. In addition, UNISOR has provided a collegial, university atmosphere for the education of graduate students within the hi-tech environment of a national laboratory. To date, 21 graduate students have completed their thesis research at UNISOR (9 M.S. and 12 Ph.D.) and 19 more are in various stages of completion (4 M.S. and 15 Ph.D.).

The idea for UNISOR was conceived at Vanderbilt University in 1969 following the formation there in 1968 of a university-users steering committee, chaired by J. H. Hamilton, which was organized to assist the Oak Ridge National Laboratory in its effort to establish a heavy-ion accelerator facility (later named Holifield). Hamilton realized that with the availability of heavy-ion beams, placing an isotope separator *on-line* to the accelerator would open up new areas of nuclear structure research, particularly research on nuclei far from stability. One must keep in mind that in 1969 the situation *vis-a-vis* nuclear physics research was quite different than at present. There were no *users groups* to speak of, national laboratories kept to themselves, universities had their own in-house programs, and state governments did not put resources into national laboratories. It was Hamilton who conceived of the revolutionary idea that universities and state governments might combine to purchase and locate major pieces of instrumentation at a national laboratory and pledge to provide a sizeable fraction of the operating costs for an extended period of time.

UNISOR officially began in July 1971 when Emory University, Furman University, Georgia Institute of Technology, Louisiana State University, Tennessee Technological University, University of Alabama (Birmingham), University of Kentucky, University of Massachusetts, University of South Carolina, University of Tennessee, Vanderbilt University, and Virginia Polytechnic Institute and State University joined with Oak Ridge National Laboratory and Oak Ridge Associated Universities to form a consortium and to submit a proposal to the Atomic Energy Commission. In that proposal the universities and the State of Tennessee pledged to provide more than 40 percent of the initial capital funds ($550,000) and 40 percent of the operating funds ($150,000) for at least five years. Since the primary capital equipment item at that time was an isotope separator, the consortium chose the acronym UNISOR to stand for UNiversity Isotope Separator at Oak Ridge. Oak Ridge Associated Universities became the fiscal agent for the consortium, J. H. Hamilton of Vanderbilt was elected chairman of the UNISOR Executive Committee (one member from each of the participating institutions), and E. H. Spejewski was selected to be the Director. The formal UNISOR dedication took place on June 19, 1972.

It is not intended here to discuss, in narrative form, the sequence of events that transpired during the development of UNISOR. That chronology is presented in another section. Also, since comprehensive discussions of the UNISOR research program are presented in other papers of this volume, only a few highlights of the research program are presented here. This is done with a view to showing that UNISOR has maintained its position at the forefront of nuclear structure research through the steady implementation of new instrumentation and new experimental techniques on an approximate five-year cycle.

The isotope separator was installed during the summer of 1972 and the first on-line work began on September 2 of that year. Complete spectroscopy (locating and quantifying all transitions and energy levels below about 1.5 MeV) was developed and quickly became the standard for spectroscopy at UNISOR. This type of research first revealed that in the lightest Hg isotopes (A=184,186,188) deformed states coexist with the near spherical ground state structures [J. H. Hamilton *et al.*, Phys. Rev. Lett. 35, 562 (1975)]; and provided critical tests of then current theories and stimulated the development of new theories that yield shape coexistence at zero spin. These Hg isotopes continue to represent one of the classic examples of nuclear shape coexistence [J.M. Eisenberg and W. Greiner, Nuclear Models, third revised edition, vol. 1, 1987, pp 283-4]. In the mid-1970's, high-performance conversion electron spectroscopy based on electron-gamma coincidence correlations was developed. This innovation, in conjunction with complete spectroscopy, provided the detailed systematics of shape coexistence in the Z=82 region which revealed the connection between deformation and the occupation of intruder states (single particle states of higher shells): most notably the demonstration that intruder states have a minimum energy at mid-shell of the other kind of nucleon (e.g. in the Z=82 region for N=104) [A. G. Schmidt *et al.*, Phys. Lett. 66B, 133 (1977)]. Additionally, UNISOR research, in conjunction with in-beam spectroscopy work, first revealed deformations in the ground states of the light Kr isotopes comparable to the superdeformed bands reported in the A=130 and 190 regions (3:2 axis ratio) and described the origin of the deformation in terms of reinforcing shell-gaps. The term *superdeformation* was used in that paper [R. B. Piercey *et al.*, Phys. Rev. Lett. 47, 1514 (1981)].

The UNISOR collinear laser facility was installed in 1981 and quickly demonstrated that the collinear laser-ion beam configuration could be used to make precise measurements of atomic lifetimes [M. L. Gaillard *et al.*, Phys. Rev. A26, 1975 (1982)]; and to test the time dilation formula in special relativity to a few parts per ten thousand [P. Juncar *et al.*, Phys. Rev. Lett. 54, 11 (1985)]. By utilizing laser hyperfine structure measurements, UNISOR research proved and explained that the deformation in the light Tl isotopes increased with decreasing mass number even though the band structure remained unchanged [J. Bounds *et al.*, Phys. Rev. Lett. 55, 2269 (1985)]. Also, alpha-decay-rate measurements provided additional evidence that the Z=82 configuration may not be magic

(closure of the energy gap) for nuclei with N near the mid-neutron shell region [K. S. Toth *et al.*, Phys. Rev. Lett., 53, 1623 (1984)].

UNISOR research provided the early evidence that electric monopole transitions are associated with shape coexistence [E. F. Zganjar *et al.*, Hyp. Int. 43, 321 (1988)], and that precise conversion-electron-gamma coincidence spectroscopy is often required to extract this information [C. D. Papanicolopules *et al.*, Z. Phys. A330, 371 (1988)]. The utility and precision of the coincidence data, and all other types of on-line experiments as well, were greatly enhanced in the mid-1980s following major advances in ion-source efficiency which were initiated by H. K. Carter who became Director in 1985.

The UNISOR On-line Nuclear Orientation facility (based on a ^{3}He/^{4}He dilution refrigerator) began operation in June 1988. Of the four on-line facilities in the world, it is unique in that it enables one to measure to 4th order in the angular distribution, thus enabling one to obtain unique values for multipole mixing ratios. One of the important results from this facility, which has a bearing on shape coexistence and intruder states, involves multipole mixing measurements in ^{194}Pt. The results indicate that by combining conversion coefficient measurements with E2/M1 ratios, obtained from anisotropy measurements using the nuclear orientation facility, one is able to obtain the actual fraction of electric monopole strength in I^{π} to I^{π} transitions [Y. Xu *et al.*, Hyp. Int. (proceedings of the Second International Conference on On-Line Nuclear Orientation, Oak Ridge, TN, October 16, 1991), in press; and to be published].

It was decided in 1981 that UNISOR needed a theoretical component, and Georg Leander of Lund University was hired. This proved to be an exceptionally good choice and, until his untimely death in 1988, UNISOR researchers and graduate students enjoyed a most stimulating interweaving of experiment and theory. One of Leander's first major papers, which resulted from this interaction, involved the onset of deformation in the neutron-deficient Sm region [Phys. Lett. 110B, 17 (1982)]. One of his last papers, completed while he was ill, is a detailed treatise on the ideas of spontaneous symmetry breaking in the nuclear intrinsic frame [Phys. Rev. C37, 2744 (1988)]. Ragnar Bengtsson, also of Lund University, was hired in 1990 and he immediately began to fill the void left by the death of Leander. In 1991 Bengtsson organized the first of what will be a series of Hands-On Nuclear Structure Theory Workshops. This was an innovation greatly appreciated not only by nuclear structure theorists and experimentalists, but especially by the graduate students.

One of the things that makes the UNISOR consortium work so well is the large number of meetings, brainstorming sessions, and workshops that it organizes. These are too numerous (3 or 4 per year) to list in the chronology below, but one can give an example: In June 1988, an *in-house* workshop on on-line nuclear orientation was held at the Joint Institute with 41 participants comprised of 15 faculty members, four postdoctoral research associates, nine graduate students, and 11 staff members from five national laboratories (ORNL, INEL, ILL, LANL, NIST) and two from private laboratories.

Although UNISOR is a consortium with a membership of universities which contribute real dollars on an annual basis ($8,000 per university), and which contribute considerable resources in ancillary ways as well (e.g., human resources such as graduate students and postdoctorals, equipment items, and electrical and mechanical shop work), it nonetheless operates as an open users facility. A large number of experiments have been conducted at the facility by non-members, both from the United States and Europe. Some are done in collaboration with UNISOR member scientists and some are not. Any experiment which passes the scientific merit test of the Holifield Program Advisory Committee, and for which UNISOR has the capability, is carried out.

The UNISOR facility is unique in the United States in its ability to provide information on the low-energy, low-spin structure of nuclei far from stability which is not easily obtainable in other ways. Some examples include: ground state and isomeric state spins, precise magnetic moments, quadrupole moments (static deformation), nuclear *rms* radii, identification and classification (definite spins and parities) of both yrast and non-yrast states up to a few MeV, the precise determination of transition strengths and multipole mixing ratios, and the precise determination of the monopole mixing strength. At UNISOR, one is able to isolate nuclei in long-lived states (ground states and isomers with $T_{\frac{1}{2}} \geq 1$ sec) such that they can interact through their moments with selected environments. Such control over the nuclear many-body problem is unique.

Still, with all the experimental capability of the UNISOR facility, members of the collaboration continued to plan for the future. They joined with scientists from Vanderbilt, Idaho Nuclear Engineering Laboratory, and Holifield to help design and obtain funding for a new generation recoil mass separator. Construction of this instrument is to begin in 1992. It will be the World's most capable instrument of that type and, when operated on-line to a radioactive ion-beam accelerator, will enable UNISOR nuclear structure research to reach combinations of neutrons and protons which are presently unexplored. This will enable one to further test current theoretical ideas and, as happened on UNISOR's first trek far from stability, to uncover unanticipated new physics.

Successful operation of an initiative in which 14 institutions provide resources and which is located at a national laboratory requires an outlook quite different from that of either a university or a national laboratory. In making the consortium work so successfully for over 20 years, UNISOR is not only the first, but probably the best example of a users consortium. That the UNISOR collaboration continues to this day, while others have come and gone, is a tribute to those who created it and to those who have sustained it. It is also a tribute to the staff of the Holifield Heavy Ion Research Facility who provided a fertile environment in which UNISOR could thrive.

Notable Quotes

"In these days of austerity in the physical sciences, it's a particular pleasure to be able to point to a project that goes counter to that trend. UNISOR is remarkable, not only for its sheer existence, but also for the extraordinary measure of cooperation between so many institutions that it represents." - Alvin M. Weinberg, Director Oak Ridge National Laboratory. At the dedication, June 19, 1972.

"The number of young nuclear scientists involved is encouraging, and their vigor augurs well for the success of the program." - The first Advisory Committee Report, 1974.

"The UNISOR collaboration continues to impress the Advisory Committee in exhibiting an atmosphere of dedication and cooperation among the users. The UNISOR staff has continued to do an excellent mature job of facility development and operation. We are please to comment on the high quality of the experimental facility at UNISOR." - Advisory Committee report, 1976.

"The Advisory Committee is pleased to find a growing sense of maturity in the UNISOR collaboration. The level of skills of the users and the in-house staff continues to grow in a healthy manner. The spirit of cooperation among the members of the UNISOR consortium continues to impress us as a dominant factor in the many accomplishments to date at the facility. - Advisory Committee report, 1978.

"We view the research program of the UNISOR consortium to be healthy and vigorous. The program is developing the diversity necessary for a balanced approach to nuclear structure physics." - Advisory Committee report, 1979.

"In basic nuclear research, we have two outstanding success stories--the University Isotope Separator at Oak Ridge (UNISOR) and the Joint Institute for Heavy Ion Research." - Edward A. Friedman, Director Office of Energy Research, U. S. Department of Energy, 1980.

"The increasing diversity of the UNISOR program is very impressive." - Advisory Committee report, 1981.

"We see the scientific program at UNISOR maturing in a very satisfactory way. The last Advisory Committee saw the opportunity for HHIRF/UNISOR to become the leading center of nuclear structure in the U.S. We see that this goal is nearer." - Advisory Committee report, 1984.

"If one does not want to neglect advanced scientific education at our universities, it is necessary to proceed as you here in Tennessee have demonstrated to the world in an exemplary way: You have initiated, very successfully, important steps in new directions of research, as was done with UNISOR, and created, with the heavy ion institute, an intellectual center and meeting place of unique character indeed." - Water Greiner, Symposium "Reflections and Directions in Low Energy Heavy-Ion Physics," Oak Ridge, TN, October 14, 1991.

Chronology

1968 A university users group steering committee for Oak Ridge National Laboratory was formed in March with J. H. Hamilton as chairman.

1969 The idea for UNISOR was conceived at Vanderbilt University in November.

- J. H. Hamilton (Vanderbilt University) and William Bugg (University of Tennessee) approached Alex Zucker (Associate Director, ORNL) and Robert Livingston (Director, ORNL Electronuclear Division) about the UNISOR concept.

- Hamilton and Bugg approached Tennessee's Governor Buford Ellington for support.

1970 Hamilton and Bugg requested William Pollard (Executive Director, ORAU) to assist with the complex organizational structure involved in forming a consortium of public and private universities, a national laboratory, a state government, and a federal agency.

- The first of a series of bi-monthly meetings of the founding UNISOR members began in February and continued throughout 1970.

1971 UNISOR officially came into being in July, with the signing of memoranda of understanding between the universities and ORAU and with the submission of a research proposal to the Atomic Energy Commission.

1972 Eugene Spejewski became the first permanent UNISOR Director and Ronald Mlekodaj the first staff scientist.

- ORAU, with Executive Director Pollard's considerable help, became the fiscal agent for the UNISOR research contract with the Atomic Energy Commission.

- The UNISOR wing to the Oak Ridge Isochronous Cyclotron building was completed in January.

- The UNISOR isotope separator was delivered in April.

- The UNISOR dedication took place on June 19.

- The first successful on-line test of the isotope separator took place in September.

1974 H. K. Carter was hired as the second staff scientist after two years as Research Associate.

- A three-person Advisory Committee and formal Information Meetings were established.

1976 Two additional beamlines were added to the isotope separator.

- The University of Massachusetts withdrew from membership.

1979 The conference "Future Directions in Studies of Nuclei Far From Stability" was organized by UNISOR (J. H. Hamilton conference chairman) and held at Vanderbilt University.

- The proposal for a UNISOR laser facility was submitted to the U. S. Department of Energy.

1981 The UNISOR laser facility became operational.

- The UNISOR lab flooded (approximately 4 feet of water) because of a broken water main.

- Emory University withdrew from membership.

- Georg Leander was hired to be the UNISOR theorist.

1982 The conference on Lasers in Nuclear Physics was co-sponsored by UNISOR.

- Virginia Polytechnic Institute and State University withdrew from membership.

UNISOR's tenth anniversary was celebrated at the SESAPS meeting in Lexington, Kentucky, October 28, 1982.

1983 A group of UNISOR scientists traveled to Louvain, Belgium to participate in an on-line nuclear orientation experiment.

- Mississippi College joined UNISOR.

1984 Funds were acquired to purchase an Oxford Instruments dilution refrigerator for the UNISOR nuclear orientation facility.

- UNISOR graduated from its "temporary" quarters in the trailers and moved to the newly completed second building of the Joint Institute for Heavy Ion Research.

1985 Eugene Spejewski resigned as director to take an administrative position at Oak Ridge Associated Universities. Ken Carter was appointed Director.

- The University of South Carolina withdrew from membership.

1986 The $^3He/^4He$ dilution refrigerator was ordered from Oxford Instruments.

- Ron Mlekodaj resigned as staff scientist to take a position with Oak Ridge National Laboratory.

- The University of Alabama (Birmingham) withdrew from membership.

1987 Oregon State University joined UNISOR.

- The University of Maryland joined UNISOR.

- Modernization of the isotope separator was initiated.

1988 The Executive Committee authorized the purchase of a new UNISOR data acquisition system based on a Digital Equipment Microvax Computer and Nuclear Data front-end and software.

- The $^3He/^4He$ dilution refrigerator and associated beam lines which make up the UNISOR nuclear orientation facility were installed.

- Georg Leander died on May 17. His last major paper, a detailed treatise on the ideas of spontaneous symmetry breaking in the nuclear intrinsic frame, was completed during his illness. [Phys. Rev. C37, 2744 (1988)].

- A five-person Advisory Committee was established.

- The first successful test of the nuclear orientation facility took place on June 29.

1989 Mississippi State University joined UNISOR.

- Texas A&M University joined UNISOR.

1990 Ragnar Bengtsson was hired as the UNISOR theorist.

- Paul Mantica was hired as staff scientist.

1991 Symposium "Reflections and Directions in Low Energy Heavy-Ion Physics to celebrate the 20th anniversary of UNISOR and the 10th anniversary of the Joint Institute was held at the Joint Institute in Oak Ridge on October 14-15.

Organization

Founding Institutions

Emory University
Furman University
Georgia Institute of Technology
Louisiana State University
Oak Ridge Associated Universities
Oak Ridge National Laboratory
Tennessee Technological University
University of Alabama (Birmingham)
University of Kentucky
University of Massachusetts
University of South Carolina
University of Tennessee
Vanderbilt University
Virginia Polytechnic Institute & State University

From: Proceedings of The Symposium on " Reflections
And Directions In Low Energy Heavy Ion Physics"

Edited By

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and R.L. Robinson

(World Scientific)

JOINT INSTITUTE FOR HEAVY ION RESEARCH

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1. Introduction

The Joint Institute for Heavy Ion Research (JIHIR) is a unique institution in the world of nuclear physics. Conceived at Vanderbilt University in 1975, it is the result of a joint effort of Oak Ridge National Laboratory (ORNL), the University of Tennessee (UT), and Vanderbilt University (VU) to build a special university-like visitor environment at a national laboratory. In the process, the success of the JIHIR has occurred because of a new type of relationship between universities and a national laboratory, and a special collaboration between the federal government and the State of Tennessee. A Memorandum of Understanding was signed in 1982 to complete in a formal way what had started several years earlier, i.e., a cooperation and then an Institute to promote the well-being of the centerpiece of the tripartite interest, the Holifield Heavy Ion Research Facility (HHIRF). The Joint Institute support of the Holifield mission has occurred in five major ways:

1. a vigorous visitor's program, especially emphasizing nuclear structure theory;

2. on-site free sleeping and kitchen accommodations for the many experimentalists involved in Holifield measurements;

3. sponsorship of a large number of conferences, workshops, and meetings on a variety of topics;

4. direct support of the Holifield experimental program via the sponsorship of visitors dedicated to the construction or implementation of certain experimental tools and also the establishment of a mechanism for finding non-federal funds to match those of the Department of Energy for the construction of new experimental devices at Holifield; and

5. office and laboratory space and secretarial support for the faculty, postdoctoral associates and graduate students from the two member universities, and from the universities in the UNISOR consortium.

The purpose of this paper is to recount the history of JIHIR over the past decade, to review its programs in recent years, and to look forward to the role of this institute in the future evolution of Hulifield. It is hoped that the successes of the Joint Institute will provide a model for future examples of university-national laboratory collaborations.

II. Beginnings

The idea for a visitor's institute in support of Holifield grew in part form the early successes of the UNISOR collaboration (as discussed in the previous paper). UNISOR was established in 1971 to purchase and support a mass separator on-line to the Oak Ridge Isochronous Cyclotron (ORIC). The rapid implementation of the UNISOR eleven-member consortium proved that this close university-national laboratory relationship could evolve and serve as a model for the increasingly user-oriented extension of national laboratories in the 1970s. When HHIRF was funded by the Department of Energy in 1975, it was with the expressed understanding that there would be a new direction in nuclear physics. That is, Holifield was to be a facility located at a national laboratory but used by scientists from universities and laboratories around the country and world, and not a national laboratory facility used essentially by the in-house scientists. This signaled a major change in policy and led ORNL to appoint five scientists to a national advisory board to oversee the planning and construction of HHIRF, to ensure that it became a truly national facility. While serving on that panel, one of us (JHH) conceived of a Joint Institute to help ensure university scientists ready access to HHIRF. Soon after, Chancellor A. Heard (VU) accepted this unusual idea and pledged $100,000 toward the construction of a users building. The University of Tennessee soon thereafter pledged $100,000, followed by ORNL providing the additional funds for the first Joint Institute building. Even so, lengthy negotiations were held with Oak Ridge-DOE Operations before approval was received for this new cooperative venture. Shortly thereafter, the central administration at Vanderbilt University began providing $10,000 annually to fund visitors to this rapidly building heavy-ion program.

The first construction of this dedicated space adjacent to HHIRF began in 1980. Building 6007 was completed by the laboratory at a cost of $439,000, including $200,000 given by Vanderbilt and the University of Tennessee. This building opened in 1981 as user space, containing nine offices, seven sleeping rooms, and a kitchen and lounge area. The sleeping capacity of Building 6007 was later increased to twelve by conversion of some offices to sleeping rooms. The proximity of this building to Holifield, coupled with the absence of a nightly charge, has made this an extremely important aspect of user activity at Holifield. It is clear that many fewer graduate students would have been able to participate in Holifield research if this dormitory space had not been provided. Besides helping make the laboratory user-friendly for outside scientists, the institute helped to significantly enhance the scientific training of graduate students. As faculty researchers have emphasized, not only can they afford to bring there beginning graduate students for experiments, but more importantly, in the evenings the senior scientists and graduate students gather in the institute lounge to discuss the results of the day's efforts and problems, and their hopes for the experiment. Such in-depth discussions clearly enhance the research while providing graduate students with invaluable training.

Building 6007 was designed by H. Shapira of ORNL also as an experimental facility for research on energy efficiency. Consequently, there are special energy-saving features, such as the fact that one side and the roof of the building are underground.

In 1980, there also began an effort to convince the government of the State of Tennessee to fund another building at Oak Ridge to provide additional space for user programs and needs. Leaders of Vanderbilt University made initial approaches to state legislators and the governor about this. Indeed, the circumstance of a private university approaching state government for funds to benefit a national laboratory is an unusual one. Soon thereafter, support from leaders of the University of Tennessee provided a unique partnership of public and private universities in Tennessee in pursuit of a common scientific goal. This double-barreled lubby effort resulted in a 1981 appropriation by the state of Tennessee of $350,000 toward the construction of a second Joint Institute building (Bldg. 6008) at ORNL. In subsequent months, the Oak Ridge Associated Universities added $44,000 to the project to enlarge the design of the building and, thereby, provide space for UNISOR personnel. The two universities provided additional funds for furniture for the second building.

The state appropriation of funds for a new building at Oak Ridge necessitated the writing of a land-lease agreement between UT/State of Tennessee and the Department of Energy. Over two years of discussions and negotiations involving attorneys at UT, ORNL, DOE, and the State of Tennessee resulted in the signing of the land-lease agreement in 1982. A prolonged period of negotiation was necessary since this provided one of the first examples (if not the first) of a state leasing federal land for the construction of a state building, at least in the southeastern United States. It is possible that in the legal climate of 1992, a far greater amount of time would be needed for such a negotiation.

The Memorandum of Understanding between ORNL, UT and VU was signed also in 1982. This formally initiated what had begun earlier, the cooperation to operate the Joint Institute for Heavy Ion Research. This Memorandum established a Policy Council composed of one member from each institution. The Policy

Council first met in early 1983 and was composed of Associate Director Alex Zucker (ORNL), Chancellor Jack Reese (UT), and Provost Wendell Holladay (VU). These three leaders then appointed Russell Robinson, Lee Riedinger, and Joe Hamilton who are shown in Fig. 1 to serve as the institutional representatives on the Policy Council in the future, and designated Hamilton as the first director of the Joint Institute.

The construction of the second building of the Joint Institute began in the fall of 1983 after a year of assessment of needs and design of the structure. The construction was administered through the Facilities Planning Group at UT. Construction was finished in May of 1984, at which time occupation of the structure began. The Joint Institute buildings are shown in Fig. 2.

Fig. 1: Members of the Joint Institute Policy Council 1984-91 (left to right, L.L. Riedinger, R.L. Robinson, and J.H. Hamilton).

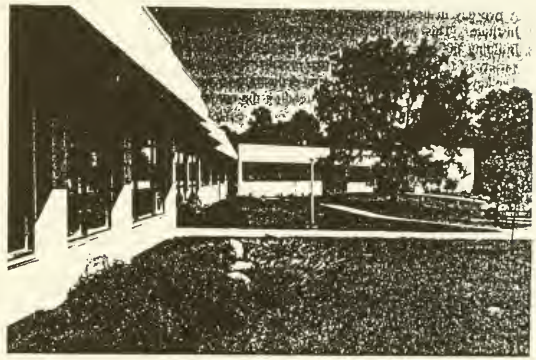

Fig. 2: The Joint Institute physical plant.

Funds for the construction of Building 6008 (the new state owned building) came before the funds to actually operate the Joint Institute were identified. An initial request was made by UT and VU to the state of Tennessee to operate the institute with a visitors program as a new type of center for higher education in Tennessee. This problem was later solved when the Science Alliance program was established at UT in the summer of 1984. The State of Tennessee, under the leadership of then Governor Lamar Alexander and then Speaker of the House Ned McWherter, established a Center of Excellence program as part if its new package of support for education. A competition was held for proposed centers of excellence throughout the higher education system in Tennessee. The Science Alliance was the winner of the first and the largest of these Center of Excellence grants. Its purpose has been to increase the level of the scientific programs at UT through a closer connection with sister programs at ORNL. In view of the long-time collaboration between the two institutions in nuclear physics, it was possible to establish the Joint Institute as a cornerstone of the Science Alliance. In July 1984, the first annual budget was established for the Joint Institute, composed of $165,000 from the Science Alliance, $30,000 from the Physics Division of ORNL $30,000 from the Department of Energy, and $12,000 from Vanderbilt University.

A two day dedication conference was held in October of 1984 at the new Joint Institute. This was the first of many conferences and workshops to occur in Building 6008 over the next seven years. The dedication was attended by a variety of top officials of the three member institutions and of state government. The keynote speaker of the opening dedication session was Nobel Laureate Glenn Seaborg. Some of the officials attending the conference are shown in Fig. 3.

Fig. 3: Dignitaries who spoke at the opening dedication of the first building of the Joint Institute (left to right, Joe LaGrone, DOE Oak Ridge; Joe Wyatt, Chancellor, Vanderbilt University, Glenn Seaborg, University of California; Joe Hamilton, Vanderbilt University; Herman Postma, Director, ORNL; Representative Marilyn Lloyd of Tennessee; Jack Reese, Chancellor, University of Tennessee; Ed Boling, President, University of Tennessee; and Wilmot Hess, U.S. DOE)

III Visitor Program

The core of the Joint Institute activities is a large vigorous program of scientific visitors. In most years, a total of $150,000 to $200,000 is spent in an overhead free manner on visitors. These funds have been amplified in many cases by using them as matching funds for other sources of support, such as sabbatical leaves. Each year there is an intentional split between visitors coming for a very short period (for several days to attend a workshop or work with resident programs), those for a term of medium length (one to three months), and those for a long term (one or more years). Since the inception of the Joint Institute, there has been a total of over 450 visitors drawing at least partial support of their expenses from institute funds. During the three years, 1988-90, over 50 scientists each year spent an average of over two months working at the Joint Institute.

Examples of areas in which the Joint Institute guests have had an impact are discussed below:

a) Nuclear Structure Theory

A natural area of support for the Holifield experimental program is in nuclear structure theory. A high level of interaction has developed between resident experimentalists and visiting nuclear structure theorists. Some have made regular pilgrimages to the Joint Institute, e.g., Walter Greiner of Frankfurt, Ricardo Broglia of Copenhagen/Milano, Amand Faessler of Tübingen, Fritz Dönau of Rossendorf, Claude Mahaux of Liege, Da Hsuan Feng of Philadelphia, Yong-shou Chen of Beijing, Jing-ye Zhang of Lanzhou, and Joachim Maruhn of Frankfurt. Others have spent a year or more working at the Joint Institute, e.g., Jerzy Dudek of Strasbourg, Witek Nazarewicz of Warsaw, Ramon Wyss of Stockholm, Paul Semmes now of Tennessee Technological University, and Zhang from Lanzhou. Although the work of this distinguished group of visitors is widely varied, one can point out several significant emphases:

1. Mesh calculation of nuclear shapes. Short visits by Nazarewicz and Ragnar Bengtsson (then from Lund) in 1985 established a program for detailed self-consistent calculations of the nuclear shape as a function of rotational frequency. An array processor was purchased for the Physics Division VAX computer; this opened the possibility of a unique and massive set of calculations. Zhang visited the Joint Institute for a year and carried out a huge number of calculations on nuclei in the rare-earth region of deformation. These were the first such systematic calculations over a wide range of nuclei, and they provided

a significant focus of interaction in subsequent years between experimentalists and theorists. This focus has been re-established by the extended visits of Nazarewicz and Wyss to the Joint Institute in the last year.

2. Ongoing FDSM interests. Another nuclear structure focus has been the Fermion Dynamical Symmetry Model, developed partially through Joint Institute support. Mike Guidry of the University of Tennessee has worked closely with JIHIR visitors, e.g., Cheng-li Wu (Jilin in China) and Da Hsuan Feng (Drexel), to make remarkable advances in the predictive powers of this model in recent years.

3. Generator Coordinator Method (GCM). Joint Institute visits by Dönau and Zhang have led to much progress in the use of GCM techniques to explain dynamical aspects of nuclear collective motion.

4. Hands-on Theory Workshop. In the summer of 1991, a unique approach to accessibility to nuclear models was tried successfully. Over 40 nuclear physicists (mostly experimentalists and many at the graduate student level) attended a two-week workshop to learn the operational details of collective nuclear models. This approach will be used as the model for a very similar workshop in Copenhagen in 1992.

5. Superdeformation. Jerzy Dudek carried out extensive calculations which exposed the unexpected regions of hyperdeforma tion. His calculations were one of the major scientific justifications in the proposal that led to the funding of Gammasphere. Chapter 3 on Scientific Justification in the Gammasphere Proposal began with a discussion and a figure of Dudek's calculations of ^{152}Dy, including superdeformed and hyperdeformed potential minima.

6. Theoretical calculations in support of experimental studies. Many of the theorists have often worked closely with experimental groups to provide calculations and theoretical analyses of experimental results. These cooperations have led to significant impact on the experimental programs by suggesting additional studies or the investigation of new phenomena. At the same time, the new experimental data often have provided confirmation of the theoretical calculations as well as stringent tests that have called for further development of the models. This interplay, often day by day, of theory and experiment has indeed been one of the exciting and fruitful contributions of the Joint Institute.

7. Support of the Theoretical Program: Theory month One of the activities that has been supported by the Joint Institute for more than five years is Theory Month. This is a one-month period when a number of nuclear theorists are invited to spend a month at the Joint Institute. Typically, between four and six theorists are invited to participate. Activities for Theory Month consist of seminar series, colloquia, and small workshops. This is a time of in-depth discussions and exchanges of ideas with scientists from around the world. The principle focus has been the support of nuclear structure and related programs. Theory Month has been remarkably successful. Included among the visitors have been J. Maruhn (Frankfurt), C. Mahaux (Leige), M. Nagarajan (Daresbury), and D. Brink (Oxford).

b) Support of the Experimental Programs

Significant Joint Institute visitor support has benefited the experimental Holifield program. One mechanism for this has been the support (full or shared) of physicists brought to help in the development of large pieces of Holifield equipment. Among these have been:

1. Cem Girit, 1987-89, to lead in the installation of the liquid-helium dilution refrigerator at UNISOR;

2. Dennis Hamilton, 1989, for the same purpose;

3. Ken Teh, 1987-89, to work on the development of the Heavy Ion-Light Ion (HILI) facility, a large array of charged-particle detectors;

4. Mark Riley, 1986-88, to assist in implementation of improvements in the Spin Spectrometer (and use of the Compton suppression Ge array);

5. Jim McNeill, 1989-90, for the same purpose.

c) Atomic Physics

Although the dominant focus of JIHIR has been heavy-ion nuclear physics, some support has benefited the heavy-ion atomic program. Visitors to work with the atomic program of Sheldon Datz and Ivan Sellin have been regularly supported, e.g., K. Groenefeld from Frankfurt, R. Schuch, Stockholm, and K. Komaki, Tokyo.

IV. Conferences, Workshops, and Meetings

A key mission of the Joint Institute is to bring scientists together in a highly interactive mode. The organization and sponsorship of a large number of workshops and conferences have had a large impact on nuclear (and to some extent atomic) physics. Table I contains the list of 31 conferences and workshops sponsored partially or wholly by the Joint Institute since 1984. All but one have taken place in the Institute and most have been organized or implemented by Joint Institute staff. These cover a broad range of topics. Eleven were based on equipment, where physics and hardware details relating to a new piece of apparatus or accelerator were discussed. Featured topics have been Gammasphere, nuclear orientation devices, recoil mass spectrometers, storage rings, and Monte Carlo computer codes. Five of the 31 workshops have been based on issues of nuclear theory, e.g., the Hands-On Theory Workshops discussed above. Those aspects of JIHIR activity, especially, has put a heavy load on the Institute staff. The success of these conferences has been to a large part due to the work of Jackie Smith, with the more recent addition of the talents of Carlene Stewart.

TABLE I

Meeting	Date	Attendees
Directions in Nuclear Structure Research/Dedication Ceremony	10/15-16/84	107
Workshop on Atomic Physics with Stored Cooled Heavy Ion Beams	1/13-15/86	50
Recoil Mass Spectrometer Workshop	6/23-24/86	50
Workshop on Heavy Ion Physics and Instrumentation for a 15-Tm Booster and Storage Ring	10/2-4/86	65
Holifield Theory Users Group	9/25-26/87	53
UNISOR Executive Committee Meeting	11/18/87	29
Workshop on the Proposal for a National Gamma-Ray Detector Facility	11/19-21/87	90
Computational Atomic & Nuclear Physics at One Gigaflop	4/14-16/88	52
UNISOR Workshop	6/21/88	45
Workshop on High Energy Nuclear Collision Monte Carlo Codes	9/12-23/88	18
Workshop on Microscopic Models in Nuclear Structure Physics	10/3-6/88	75
Town Meeting on High Energy Heavy Ion Physics	4/24-25/89	92
UNISOR Executive Committee Meeting	6/19,23/89	50
UNISOR Nuclear Orientation Workshop	6/20-23/89	55
Summer School of Computational Atomic and Nuclear Physics	7/2-13/89	72
Planning Workshop for Gammasphere	9/21-22/89	82
HHIRF Theory Users Group Meeting	3/23-24/90	46
Gammasphere Steering Committee Meeting	4/22/90	12
International Conference on Nuclear Structure in the Nineties	4/23-27/90	208
Second UNISOR Nuclear Orientation Workshop	7/31-8/2/90	33
Radioactive Beams at the HHIRF	10/2/90	40

Gammasphere Meeting	11/2/90	21
Future Forms of Collaboration Between Theorists and Experimentalists in the Field of Low Energy Nuclear Structure	2/26/91	52
Lectures on Hands-On Nuclear Structure Theory Workshop	8/5-16/91	49
Symposium on Reflections and Directions in Low Energy Heavy-Ion Physics	10/14-15/91	85
International Conference On-Line Nuclear Orientation-2	10/16-19/91	75
International Workshop on Nuclear Structure Models	3/16-25/92	65
Symposium on Nuclear Reactions "Satchlerfest"	4/15-16/92	50
Planning Committee Meeting for Radioactive Ion Beams Conference	5/28-29/92	35
Symposium on Nuclear Physics of the Universe	9/24-26/92	
Workshop on the Production and Use of Intense Radioactive Ion Beams at the IsoSpin Laboratory	10/6-10/92	

V. Mechanism for Matching Funds

An important recent aspect of the funding of large pieces of equipment has been the emphasis on local funds matching the federal monies. The Joint Institute was created from that spirit of partnership in Tennessee, and its existence allows opportunities to raise more funds for initiation of new projects. In a sense, not only has the Joint Institute brought visibility and expanded possibilities to our university programs, but also it has bought a higher responsibility to UT, Vanderbilt and the State for the health of nuclear physics programs at Holifield. This has led to a large amount of local support for specific detectors at Holifield.

a. Array of Compton-suppressed Ge detectors: $1.2 million total cost, including $125,000 from Vanderbilt and $320,000 from the University of Tennessee (through the Science Alliance program);

b. Spin Spectrometer electronics upgrade: $40,000 contribution from the Science Alliance at UT;

c. Liquid helium refrigerator: $15,000 from Vanderbilt, $75,000 from the UT Science Alliance;

d. Electronics for a neutron detector: $40,000 from Vanderbilt;

e. Compton polarimeter: $30,000 from Vanderbilt;

f. Recoil Mass Spectrometer: $500,000 from the State of Tennessee, $155,000 from the UT Science Alliance, and $155,000 from Vanderbilt;

g. Radioactive beam facility development: $100,000 each from UT and Vanderbilt.

In addition to the above list of expended funds, the State of Tennessee had committed $800,000 towards the cost of construction of Gammasphere if it had been sited in Oak Ridge.

VI. Conclusions

The Joint Institute for Heavy Ion Research has proven to be a very successful entity of collaboration centered around the Holifield facility, including collaborations between nuclear physicists (experiment and theory), between universities and a national laboratory (University of Tennessee, Vanderbilt University and Oak Ridge National Laboratory), and between state and federal government. It is a real center of activity, serving not only as a host for its visitors and conferences but also a site for most ORNL Physics Division luncheon meetings, seminars and colloquia. It is, in a real sense, university space at a national laboratory, and thus serves as a center of activity for faculty, postdocs, and graduate students. It provides an on-site dormitory and kitchen, which has allowed university groups to bring to experiments far more students than normal, and it is a fine model for new joint activities, whether in nuclear physics or in other fields of science. Indeed other "Joint Institutes" have been or are being born between two or three of the JHIR members, one

in Energy and Environment and another in Computational Science. Another will arise in the future with the anticipated Advanced Neutron Source at Oak Ridge as the centerpiece.

Changes occur in all entities, the Joint Institute and Holifield being no exceptions. At the Joint Institute, the Policy Council that has been intact from the beginning is changing, as Lee Riedinger (who served as director for four years) because of new administrative responsibilities has been replaced by Carrol Bingham. At Holifield, a change to a radioactive ion beam facility has begun. This change will be supported by the Joint Institute, and a new emphasis on nuclear astrophysics will be found in future visitor and conference programs. The next Joint Institute Workshop is on nuclear astrophysics in September, 1992. It is clear that the combined strength of Holifield and the Joint Institute can continue to provide much to the nuclear structure community in the coming decades, as it has in the past, and expand into new areas. Indeed the strong interplay between theory and experiment made possible by the Joint Institute will be even more important in the years ahead, as more exotic nuclei (to even beyond the proton drip line), new phenomena like hyperdeformation, and other unexpected phenomena are explored at the Oak Ridge Radioactive Ion Beam Facility.

VII. Acknowledgements

The authors wish to acknowledge the strong support of a number of key individuals: Alex Zucker, Associate Director, ORNL; James Ball, Director of ORNL Physics Division; Presidents Ed Boling and Joe Johnson, University of Tennessee; Chancellor Jack Reese, University of Tennessee; William Bugg, Head of the UT Physics Department; Connie Haynes, Science Alliance secretary in UT Physics; Thomas Callcott, Director of the UT Science Alliance; Ken Carter, UNISOR director; Chancellors Alexander Heard and Joe Wyatt, Vanderbilt University; and Dean Jacque Voegeli, Vanderbilt University.

Appendix C

A Center of Excellence at the University of Tennessee UT/ornl Science Alliance

Oak Ridge Summit on Science, Environment, and Technology - June 1-2, 1995

Sharing Resources Creates Opportunity - Alliances that get you more for your research dollar

Attempts to establish formal links between The University of Tennessee, Knoxville (UTK) and Oak Ridge National Laboratory (ORNL) date back at least 30 years. The UT/ORNL Science Alliance is the best-known and most-enduring and successful of these. It was established in July 1984 as part of Governor Lamar Alexander's "Better Schools Program," which ratified similar Centers of Excellence at universities throughout Tennessee. The Science Alliance is the largest of these, with an annual budget of $3.5 million. This figure represents over 20 percent of the state's annual budget for such centers.

The primary mission of the Science Alliance is to promote scientific research and educational collaboration between UTK and ORNL. It does so through Distinguished Scientist and Collaborating Scientist programs, joint institutes, graduate and post graduate funding, faculty awards, and start-up support for new projects. The Science Alliance is the primary vehicle through which UTK and ORNL share personnel, specialized instruments, and financial resources to achieve mutual goals.

HISTORICAL PERSPECTIVE

Several issues converged in the late 1970s and early 1980s to bring about the Science Alliance. Reports from the Energy Research Advisory Board and the Federal Laboratory Review Panel had identified weak links between universities and the major federal research institutions, a condition both groups found "alarming," especially if the United States intended to continue world-wide scientific leadership.

"At a time when America is looking for ways to emphasize science and technology," wrote, then Governor Lamar Alexander in a March 1983 letter to Secretary of Energy Donald Hodel, "[a] coalition between a U.S. world class laboratory and our state's comprehensive research university will be a national milestone."

Equally important to science faculty and administration at UTK was the need to improve the national ranking of their graduate education and research programs. In the decade prior to 1984, laboratories at UTK had suffered from decline in state and federal appropriations for major equipment. The Science Alliance provided the means to improve this situation, not only attracting top level scientific expertise to joint UTK and ORNL positions but also drawing matching external funds for new science initiatives and improvements to facilities.

THE DISTINGUISHED SCIENTIST PROGRAM

Plans for a formal alliance actually began with the Distinguished Scientist Program. As originally conceived, the program was to include up to 30 esteemed scientists holding joint positions and be administered by one of Tennessee's Centers of Excellence. Thus, when the Science Alliance formally opened in July 1984, Dr. Gerald Mahan, a solid state physicist, was already hired, arriving that August. This spring, that hire paid huge dividends when Mahan became UTK's first member of the National Academy of Sciences. Mahan's

induction to the National Academy is his reward for sustained excellence and prominence in science, and much of that work was done with the support of the Science Alliance Distinguished Scientist Program.

During the years that followed, the Science Alliance continued to seek out scientists of similar caliber, adding such highly respected faculty/scientists as environmental microbiologist Dr. David White (hired in 1986), a recent winner of the coveted Clarke Prize, which, along with it's decorative gold medal, carries a $50,000 stipend; computer scientist Dr. Jack Dongarra (1989), author of the award-winning PVM software, which helps scientists aggregate their computing resources; Dr. David Joy (1987), known internationally for his work in electron and X-ray microscopy and electron holography; analytical chemist Dr. Georges Guiochon (1987), a recent Humboldt Senior Scientist who wrote the book on chemical separation techniques with his pioneering work in gas and liquid chromatography; Dr. Bernhard Wunderlich, (1988) chemical thermodynamics of solid state polymers, winner of the 1993 Prize for Applied Chemical Thermodynamics from the Swiss Society for Thermal Analysis and Calorimetry, an award rarely given to scientists outside of Europe; Dr. Ward Plummer, (1992) subatomic surface structure of materials, whose ability to organize national and international collaborations has brought new funding and science to East Tennessee; Dr. Peter Cummings (1994), a chemical engineer whose computer simulations predict how molecules in fluids interact and change as other substances are added or removed, saving the expense and time of repeated preliminary experimentation. Today, 12 distinguished researchers hold joint UT/ORNL posts. UTK provides 50 percent of the program's budget through the Science Alliance; the other 50 percent is provided by ORNL from U.S. Department of Energy funds. The appointments include a sizeable fund for graduate student and postdoctoral support, based at both UTK and ORNL.

COLLABORATING SCIENTISTS

The Collaborating Scientists Program makes it possible for UTK and ORNL to share scientists at all levels, who are already employed by one of the two institutions. Like distinguished scientists, collaborating scientists have access to the resources of both institutions, saving UTK and ORNL the time and money of duplicate efforts. Unlike the distinguished scientists, collaborating scientists are based in a home institution either at ORNL or UTK, and spend an agreed upon percentage of their time at the other institution. To date, eight scientists have joined the program, including three physicists, a computer scientist, a mechanical and aerospace engineer, an environmental economist, a library and information scientist, and a mathematician.

JOINT INSTITUTES

Science Alliance-supported research institutes bring together researchers from UTK, ORNL, Vanderbilt University, and other private and public organizations around the world. In all, the center supports four of these, the Joint Institute for Heavy Ion Research (JIHIR) being the oldest. Established in 1984, JIHIR led UTK and ORNL to international prominence in nuclear structure physics. Housed in two buildings adjacent to ORNL's Holifield Radioactive Ion Beam Facility (HRIBF) [formerly known as Holifield Heavy Ion Research Facility], JIHIR conducts conferences and workshops and sponsors research of visiting scientists. As the field of nuclear physics has changed, so has the Holifield facility and JIHIR. Currently, the Holifield is being converted into the country's first radioactive ion beam accelerator, a change that will expand JIHIR research into astrophysics and formation of elements.

In it's role as catalyst, the Science Alliance recently provided matching seed funds to the new Institute for Rare Isotope Measurements, enabling its director to secure substantial external funding from both the National Science Foundation and the U.S. Department of Energy. Similarly, the Joint Institute for

Computational Science (JICS), which was initiated with funds from the Science Alliance, now receives more than half of its total funding from other sources.

Referring to itself as the "friendly interface between researchers and parallel computing," JICS has become Tennessee's principal resource for training faculty, staff and graduate students in parallel computing. Established in 1991, JICS brings together skilled parallel computing specialists with interdisciplinary research scientists. Research includes collaborations with ORNL and UTK physicists, chemists and biomathematicians. Parallel computing cuts the time to execute a program from days or weeks, to a matter of minutes or hours. The powerful UTK and ORNL combined portfolio includes a MasPar MP-2, Thinking Machines CM-5, Kendall Square KSR1, and an Intel iPSC/860.

OTHER PROGRAMS

The Science Alliance also promotes East Tennessee's scientific excellence in a number of smaller ways. For example, graduate student supplements account for over $500,000 of the annual Science Alliance budget, providing assistance to approximately 100 students who do research at both UTK and ORNL. These stipends are crucial because they allow UTK science departments to compete with the nation's top universities for outstanding graduate students. In addition, each year approximately 80 undergraduates come to East Tennessee to study in UTK or ORNL laboratories through the Summer Research Fellows Program. For most, this is their first exposure to a high-level research environment, and the experience is a strong inducement to pursue graduate study in the sciences.

Science Alliance Faculty Research Awards have helped to recruit and retain top quality faculty in East Tennessee. Initiated in 1985, these awards provide annual recognition and financial incentive to top UTK science faculty. Financial support for the program comes from UTK central administration. Steadily improving applications over the years indicate the positive effect these awards have had on faculty recruitment and performance.

THE SCIENCE ALLIANCE TODAY

In July 1994, the Science Alliance marked ten years as the primary channel for promoting research and educational collaboration between UTK and ORNL. One UTK chemistry faculty member with a long record of ORNL collaborations likened the role of Science Alliance to that of "a lubricant." He credits the center with easing the assembly of "uniquely capable" UT/ORNL research teams, such as the one he is part of, which combines the capabilities of UTK's synthesis and mass spectrometry groups with ORNL's Health and Safety Research Division, Nuclear Magnetic Resonance group, and physics groups. Because of the global nature of scientific research and the increased productivity that occurs when interests are combined, Science Alliance Director, Dr. Thomas A. Callcott has expanded this focus to include resource sharing wherever possible. With these goals in mind, the UT/ORNL Science Alliance will continue its stewardship of valuable research resources.

Appendix D

Recent Facilities with Joint University - State - DOE Funding

a. Array of Compton-suppressed Ge detectors: $1.2 million:
Total cost, including $125,00 from Vanderbilt and
$320,000 from the University of Tennessee
(through the Science Alliance program);

b. Spin Spectrometer electronics upgrade: $40,000
contribution from the Science Alliance at UT; Total cost $100,000

c. Liquid helium refrigerator: $15,000 from Vanderbilt,
$75,000 from the UT Science Alliance; $40,000 UNISOR; Total cost $200,000

d. Electronics for neutron detectors: $40,00 from Vanderbilt
In addition, the detectors were built at Vanderbilt.

e. Compton polarimeter: $30,000 from Vanderbilt; Total cost $50,000

f. Recoil Mass Spectrometer: $500,00 from the State of Tennessee,
$155,000 from the UT Science Alliance, and $155,00 from Vanderbilt;
$250,000 UNISOR universities; $300,00 Martin Marietta - ORNL non
DOE funds, Total cost Spectrometer plus building $3,800,000

g. Radioactive beam facility development: $100,000 each from UT
and Vanderbilt.

h. 12 clover Ge detector arrays: $50,000 Vanderbilt, $50,000 UT,
$50,000 UNISOR Universities, State of Tennessee $150,000;
Total costs: $1,800,000

i. Focal plane detections for RMS: $55,000 UNISOR
$20,000 Vanderbilt, $170,000 English universities;
Total cost $250,000

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